Alternative Market Structures for Derivatives

Söhnke M. Bartram* and Frank Fehle**

Abstract

In this paper, we compare option contracts from a traditional derivatives exchange to bank-issued options, also referred to as covered warrants, whose markets have grown rapidly around the world in recent years. While bank-issued option markets and traditional derivatives exchanges exhibit significant structural differences such as the absence of a central counterparty for bank-issued options, they frequently exist side-by-side, and the empirical evidence shows that there is significant overlap in their product offerings. We examine trading costs and liquidity in both markets and find that bank-issued options have smaller quoted percentage bid-ask spreads than traditional option contracts by an average of 4.3%. The bid-ask spread difference manifests itself in a highly regular fashion in that ask (bid) prices for bank-issued options are consistently higher than comparable ask (bid) prices for traditional option contracts. The difference of the bid prices is larger than the difference of the ask prices resulting in smaller bid-ask spreads for bank-issued options. The empirical analysis also indicates that bid-ask spreads in either market are lowered by competition from the other market. We present a potential explanation for the co-existence of the two market structures which suggests that the bank-issued option market caters more towards retail investors with predominantly speculative motives while traditional derivatives exchanges may cater more towards institutional investors with predominantly hedging motives.

Keywords: Options, Market Design, Microstructure, Bid-Ask Spreads

JEL Codes: G10, G13

This Version: December 8, 2003

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We are indebted to Michael Brennan, Philip Brown, Ian Cooper, Patrick Dennis, Shingo Goto, Bart Lambrecht, Stewart Mayhew, Ted Moore, Narayan Naik, Greg Niehaus, Peter Pope, Mark Shackleton, Stephen Taylor, Sergey Tsyplakov, Xinzhong Xu, Pradeep Yadav, Steven Young, and seminar participants at the 2003 FMA meeting, the 2003 European Finance Association meeting, Lancaster University, and the University of South Carolina for helpful comments and suggestions. We also thank Wolfgang Gerhardt at Sal. Oppenheim, Serguei Nemtsev at KKMDB, Pascal Nörrenberg at Citibank, Stephan Schubert and Michael Schwetje at OnVista AG, and Andreas Comtesse, Grushenka Straub, and Torsten Ulrich at EuWax. Anneke Kraan provided excellent research assistance. Boerse-Stuttgart AG, EuRex Frankfurt AG, KKMDB, and OnVista AG offered invaluable assistance with the data used for this project. Frank Fehle gratefully acknowledges a summer research grant from the University of South Carolina, and research visits at Maastricht University and Lancaster University. Söhnke Bartram gratefully acknowledges research funding by the Maastricht Research School of Economics of Technology and Organizations (METEOR). An earlier version of this paper was awarded the Josseph de la Vega Prize 2003 by the Federation of European Securities Exchanges.

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This Version: December 3, 2003

1. Introduction

Well-functioning financial markets are of considerable importance for resource allocation and risk transfer and thereby the overall welfare of an economy. Finance practitioners as well as regulators thus pay considerable attention to the structure of existing financial markets and the design of newly-developing financial markets. In the area of derivatives markets, one of the biggest success stories in recent years has been the growth in markets around the world for bank-issued options, also sometimes referred to as covered warrants. Bank-issued options are exchange-traded, securitized options issued by banks and other financial institutions. The options are non-standardized, and individual issuers are free to choose any option characteristics for which they expect investor demand. Each issuer is the sole counterparty to its own option contracts.[1] However, issuers compete by issuing similar or identical options and usually obligate themselves to serve as market makers for their own products on an organized exchange. For investors, bank-issued option markets represent an alternative to traditional derivatives exchanges such as the CBOE, and trading activity in bank-issued options is frequently of considerable magnitude compared to trading activity in option contracts from traditional exchanges. It is thus important and useful to study these alternative market structures.

While bank-issued option markets and traditional option exchanges exhibit significant structural and institutional differences, they frequently exist side-by-side offering many options with identical or similar characteristics. This study provides the first comprehensive empirical comparison of bank-issued options to option contracts from a traditional derivatives exchange. We analyze the characteristics of options offered in both market types and assess the degree of overlap between the markets. Secondly, we compare liquidity provision under the two market structures and examine how it is affected by competition within and between the markets. Liquidity provision is mainly assessed using bid and ask quotes and the resulting quoted bid-ask spreads, but we also analyze other dimensions/measures of liquidity such as effective spreads, minimum trade sizes, maximum bid-ask spreads, and brokerage costs. Finally, we also ask why and how such differently organized markets for similar or identical financial assets can co-exist successfully rather than consolidate into one market structure.

[1] Since each issuer is the sole counterparty, options are not exchangeable between issuers or between the bank-issued market and a traditional derivatives exchange in the sense that an option position entered into with a particular issuer cannot be liquidated with another issuer or on the derivatives exchange. Furthermore, arbitrage between issuers and market types is restricted by the fact that investors cannot write bank-issued options, thereby imposing a short-sale constraint.

The empirical evidence shows that there is considerable overlap in the product offerings between the two market types. For our sample, options in both markets with identical or very similar features for just six heavily traded underlying assets account for roughly one quarter of the total equity and equity index option trading volume in either market. With respect to liquidity provision, bank-issued options have significantly smaller quoted percentage bid-ask spreads by an average of 4.3%. The bid-ask spread difference between the two market types manifests itself in a highly regular fashion in that ask prices for bank-issued options are consistently higher than comparable ask prices for traditional option contracts. At the same time, bank-issued option bid prices are consistently higher than the comparable bid prices from the traditional exchange. The difference of the bid prices is larger than the difference of the ask prices resulting in smaller bid-ask spreads for bank-issued options.

Despite the above differences in liquidity provision, we also present evidence that bid-ask spreads in either market are lowered by competition from the other market. This finding is broadly consistent with related work by Battalio, Hatch, and Jennings (2003), De Fountnouvelle, Fishe, and Harris (2003), Mayhew (2002), and Wang (2000) examining the effect of competition among traditional option exchanges on liquidity and market-making quality. The multivariate analysis shows that competition among issuers within the bank-issued option market also benefits investors via more competitive quotes. Furthermore, we provide evidence of a trade-off between quote competitiveness and other market-making features consistent with theoretical work such as Hodrick and Moulton (2003) which is based on the notion that liquidity is multi-dimensional. Finally, we present a potential explanation for the co-existence of the two market structures which suggests that the bank-issued option market caters more towards retail investors with predominantly speculative motives while traditional derivatives exchanges may cater more towards institutional investors with predominantly hedging motives.[2]

The remainder of the paper is organized as follows. The next section explains the structural and institutional features of bank-issued option markets in more detail. Data and methodology are discussed in Section 3. Section 4 gives the empirical evidence, containing univariate and multivariate comparisons of quotes and spreads in both markets, robustness checks, and univariate analyses assessing the effect of competition between the two market types. Section 5 concludes.

[2] In related work, Franke, Stapleton, and Subrahmanyam (1998), Leisen and Judd (2000), and Franke and Weber (2002) study how investor heterogeneity can give rise to option supply and demand. However, these studies do not connect option clienteles, such as hedgers and speculators, to market design and microstructure issues.

2. Market Structures of Bank-Issued Options vs. Option Contracts on Derivatives Exchanges

Many European and Asian countries have sizable markets of options also referred to as covered warrants that are issued by banks as stand-alone securities. These bank-issued options are traded on organized exchanges, such as the European Warrant Exchange (EuWax) in Germany, the NextWarrants segment of Euronext, the extraMARK segment of the London Stock Exchange, the MCW segment of the Borsa Italiana in Milan, the Hong Kong Stock Exchange, or the Australian Stock Exchange. Bank-issued option markets are thus different from warrant markets in the U.S., where the term warrant typically refers to option securities written on an issuing corporation's own stock. Such U.S. warrants are originally issued in a bundle with another security, e.g. a corporate bond, but can subsequently be traded separately.

Almost all bank-issued options are covered options in the sense that the issuer is obligated (as stated in the prospectus) to hedge all options sold. Thus, bank-issued options are generally considered to be free of default risk. In the prospectus, issuers often also commit to make a market for their own options by quoting ask and bid prices on at least one exchange or electronic information system, such as Reuters, until the option's expiration. The quality of the market-making is usually further detailed by providing a maximum bid-ask spread, minimum quote depth, and minimum trade size as, for example, in Goldman Sachs (2000). Investors can purchase bank-issued options using regular brokerage accounts, with orders being filled either on an exchange listing the desired option or directly with the issuer as an over-the-counter transaction. It is typically not possible for investors to write bank-issued options which is equivalent to the investor shorting the option.

In addition to competition among issuing banks in the bank-issued option market itself, there are several cases in which bank-issued option markets exist side-by-side with traditional derivatives exchanges, often offering options with identical or very similar payoff functions. Examples of both markets existing side-by-side are found in Italy, where the MCW market, for bank-issued options, and the IDEM market, for option exchange contracts, even exist as segments on the same exchange, and Germany, where bank-issued options are traded on the aforementioned EuWax exchange and traditional option contracts are traded on the EuRex derivatives exchange in Frankfurt.

While precise data for all bank-issued option markets around the world are difficult to obtain, the German bank-issued option market being studied in this paper is generally considered to be the world's largest. The International Warrant Institute (2002), an industry association, estimates that in the year 2000 roughly half of the global bank-issued option trading volume as measured by paid premiums occurred in Germany. EuWax in turn dominates the German bank-issued option market

with a market share of over 90% according to Börse Stuttgart (2001). For equity and equity index options, year 2000 EuWax trading volume as measured by paid premiums represents roughly 30% of year 2000 EuRex trading volume. Thus, compared both to EuRex, its traditional derivatives exchange counterpart, and to other international option exchanges, the EuWax market is of considerable size. Back-of-the-envelope calculations indicate that the trading volume of EuWax options on the largest underlying asset, the German DAX index, would rank among the top five underlying assets on the CBOE during the same time period.

EuWax is a special market segment of the Stuttgart Stock Exchange, one of Germany's regional stock exchanges. Issuers listing EuWax options are required to make a continuous market for their options and are subject to quality control and regulation from the exchange. EuWax orders can potentially be placed with any financial institution willing to make a market. However, discussions with market participants indicate that market-making by someone other than the issuer is rare and that orders are filled almost exclusively with the issuer's market maker. All major issuers of bank-issued options in Germany make markets for their own options on EuWax.[3] Bank-issued options in Germany are subject to relatively little regulation, and as a result, banks can issue options quickly and at low cost.[4] Regulatory differences could be one of the reasons why bank-issued option markets are virtually non-existent in the U.S. while having experienced tremendous growth in many other countries. In the U.S., bank-issued options fall under the Commodity Exchange Act and are subject to regulation by the Commodity Futures Trading Commission while in other countries bank-issued options are often subject to less onerous general banking supervision.

EuRex ranks by most measures as the world's largest derivatives exchange and has many typical derivatives exchange characteristics comparable to the CBOE. Option contracts are standardized with respect to underlying asset, exercise style, expiration date, and strike price, and new contracts are created according to specific rules governing, for example, the addition of strike prices and new expiration dates. There are pairs of calls and puts for all option contracts. EuRex Clearing AG, a wholly owned subsidiary of EuRex, serves as the central counterparty and clearinghouse for all contracts. EuRex has market makers who are obligated to supply bid and ask quotes and to enter into transactions upon demand generated by an order. There are exchange-mandated maximum bid-ask

[3] According to Börse Stuttgart (2002), major issuers are BNP Paribas, Citibank, Commerzbank, Credit Lyonnais, Deutsche Bank, Dresdner Bank, Goldman Sachs, HSBC Trinkaus Burkhardt, HypoVereinsbank, Lehman Brothers, Merrill Lynch, Rabobank, Salomon Brothers (now part of Citibank), Sal. Oppenheim, Societe Generale, UBS Warburg, Unicredito Italiano, and WestLB.

[4] Discussions with Sal. Oppenheim in Germany indicate that the regulatory process for new bank-issued options in Germany typically takes less than a week, and has direct costs of only a few thousand Euros. New issues are typically advertised in the business press and via electronic media, which creates additional issuance costs.

spreads, minimum quote depths, and a minimum period for maintaining quotes. Most option contracts have several competing market makers whose parent institutions in some cases are banks that also issue EuWax options as shown in EuRex Communications (1999) and EuRex Communications (2002a).

A summary of institutional differences between EuRex and EuWax is provided in Table 1. The fact that such markedly different market structures for options can exist side-by-side while offering products that appear in many regards as substitutes raises the question of the raison d'être of the different markets. Common wisdom among market practitioners suggests that bank-issued option markets are geared towards retail investors while traditional derivatives exchanges cater more to the needs of institutional investors. The idea of differing clienteles between the two market types is supported by the fact that minimum trade sizes of EuWax options are considerably smaller than the minimum trades sizes of otherwise comparable EuRex options.[5] Furthermore, conversations with option market professionals at Sal. Oppenheim, Citibank, OnVista, EuWax and EuRex also support the notion that the two clienteles differ with respect to their motives for using options. Retail investors on EuWax are perceived typically to have speculative motives, while the typical institutional investor on EuRex is more likely engaged in hedging.

Several stylized facts are consistent with the idea that EuWax and EuRex clienteles may also differ with respect to speculative versus hedging motives. First, EuWax issuers provide many more calls than puts at a rate of roughly five to one, which does not appear to cater to investors with hedging demands, who are typically long in the underlying asset and thus need to buy put options rather than call options. Institutional investors with on-going hedging programs may also prefer the EuRex market due to its superior predictability with respect to the availability of particular contracts in the future, which is governed by detailed rules for EuRex options, while EuWax issuers are under no obligation to issue particular types of options in the future.

While it is not possible to assess clientele differences directly due to the unavailability of EuWax and EuRex data identifying the specific counterparties and their option positions, one can look at potential differences between hedgers and speculators with respect to how derivatives are used which in turn may affect trades and quotes which are observed in the available data. One such difference is that hedgers with on-going hedging programs may be more likely to hold option positions until maturity, while speculators are more likely to liquidate option positions early once the event corresponding to the investor's speculative information is realized. As a result there may be a relation between an option investor's expected holding period and his choice of market/liquidity provider.

[5] EuRex minimum trade sizes are on average approximately 40 times larger than the EuWax minimum trade sizes in our sample.

The potential relation is based on a fundamental difference between many primary markets, such as stock markets, and derivative securities markets. This difference lies in the fact that by holding a derivative security until maturity, investors can convert it into cash without requiring the liquidity services of a dealer. Buyers with a high probability of holding a derivative security until maturity may thus be less concerned with bid-ask spreads than investors in primary assets such as stocks. The former essentially face only one-way transaction costs rather than the round-trip transaction costs faced by the latter. Given a choice between two option markets, investors with a high probability of holding the option until maturity are best served buying options in the market exhibiting the lowest ask prices irrespective of the magnitude of the bid-ask spread. On the other hand, investors with a high probability of liquidating the option position before maturity may be willing to buy a more expensive option if they expect to recover the initial ask price difference via an even higher bid price difference later on.[6] The idea that expected future transaction costs affect investors' current decisions is consistent with findings by Goldreich, Hanke, and Nath (2003) showing that current liquidity premiums of U.S. Treasury securities are related to measures of expected future liquidity.

Figure 1 illustrates that, all else equal, an investor's willingness to buy a more expensive option today should increase with the expected value of the future bid price difference and with the probability of early liquidation. Furthermore, the expected future bid price difference should be higher than today's ask price difference. This is due to two effects. First, the future bid price difference is reduced by the time value of money. Secondly, the expected bid price difference is earned only with the probability of early liquidation, which can be less than one, while the ask price difference is incurred with certainty, if the more expensive option is purchased today. A bid price difference which is smaller than the ask price difference implies that bid-ask spreads are smaller in the market with higher prices. Given that investors with speculative motives should be more concerned with bid-ask spreads than investors with hedging motives, an option market catering primarily to investors with speculative motives should exhibit consistently higher ask and bid prices and smaller bid-ask spreads than a market catering primarily to investors with hedging motives. In addition, investors with a high likelihood of early liquidation should also pay more attention to other features of market-making quality affecting expected round-trip transaction costs such as guaranteed maximum bid-ask spreads, which the issuer can trade off with quote competitiveness. The appendix gives a formal presentation of the above clientele argument and shows how an implied measure of the probability of early liquidation can be recovered from observed bid and ask quotes.

[6] Similar clientele effects may exist in bond markets as bonds held until maturity incur only one-way transaction costs while bonds sold before maturity incur round-trip transaction costs.

The EuWax market structure appears to support catering to clients with a high probability of early liquidation. In particular, due to the absence of a central counterparty, EuWax options from different issuers are not exchangeable. Given that the issuer is also the primary market maker, EuWax issuers can compete based on expected round-trip transaction costs which are determined by contemporaneous ask prices and future bid prices. As argued above, investors with a high probability of early liquidation may be willing to pay a higher ask price today at the benefit of a higher bid price in the future. Thus, EuWax issuers with a reputation for high bid prices are compensated by being able to charge higher ask prices.[7] EuRex investors on the other hand are indifferent as to which market maker initially sells them an option, since it can be sold back to any other market maker in the future due to the fact that EuRex options have a central counterparty. Thus, EuRex market makers compete on contemporaneous prices alone, since a EuRex market maker offering consistently high bid prices is not rewarded by being able to charge consistently high ask prices. Finally, it is interesting to note that it is not necessary for the bid-ask quotes in the two markets to overlap as depicted in Figure 1. The EuWax short-sale constraint prevents arbitrage in a situation in which EuWax bid prices are higher than EuRex ask prices. This latter case is depicted in Figure 2. The appendix gives a formal presentation of the relation between short-sale constraint and no-arbitrage conditions.

3. Data and Methodology

3.1. Data

We obtain data on the characteristics of all EuRex and EuWax equity options and equity index options (hereafter referred to as index options) which existed during the period from May 1, 1999, until October 31, 2001. These characteristics are: underlying asset, type (call or put), exercise style (American or European), strike price, expiration date, and contract size (in units of the underlying asset) for both EuWax and EuRex options, as well as the issuing bank for EuWax options. The EuWax data are obtained from the EuWax exchange and OnVista AG, a commercial provider of financial data with a particular focus on EuWax options, who in turn obtain the data directly from the issuers.[8] OnVista also provides monthly trading volume statistics for each EuWax option, measured

[7] Since issuers are the sole counterparty to their options, investors are "captive" in the sense that the issuer could exploit them by offering very poor bid prices once a sufficient quantity of options are sold. However, such behavior will damage the issuer's reputation for future transactions and thus is unlikely to be optimal in a dynamic setting.

[8] Since all EuWax options are assigned the German equivalent of a CUSIP number, we can merge

by the number of contracts traded and the paid premiums. In addition, we obtain a complete history of year 2000 bid and ask quotes for all EuWax options from the EuWax exchange. The quotes are recorded directly from the issuing bank's market maker via EuWax's electronic limit-control-system. All quotes are time-stamped to the nearest second.[9]

The EuRex option data, which are obtained directly from EuRex, contain a complete record of all EuRex transactions during the sample period. In addition to the option characteristics, these data also contain the number of contracts traded and the transaction price. Thus, volume data comparable to the EuWax volume data can be calculated from the EuRex transactions data.[10] For EuRex options, year 2000 quotes are obtained from the capital markets database (KKMDB) at the University of Karlsruhe. The KKMDB data is recorded directly from the electronic trading system at the EuRex exchange. KKMDB quotes are time-stamped to one-hundredth of a second. Each record contains the best bid quote and the best ask quote, which are not necessarily from the same market maker out of the set of competing EuRex market makers.

3.2. Overview of Market Activity on EuRex and EuWax

Total volume as measured by paid premiums of all EuRex equity and index options during the year 2000 is 78.3 billion Euros. The comparable number for EuWax options is 22.4 billion Euros. Thus, the size of the EuWax market as measured by paid premiums is approximately 30% of the size of the EuRex market.[11] By definition, the notional volume of underlying assets represented by transactions in each market is significantly larger than the paid premiums. For EuRex equity options the ratio of notional volume to paid premiums is roughly ten-to-one. Hereafter volume always refers to paid premiums and total volume always refers to the sum of equity and equity index option volume unless indicated otherwise. As shown in Table 2, there are 37,248 different EuWax equity and index options, where options with identical characteristics but from different issuers are counted individually, and 67,577 different EuRex equity and index options. EuRex and EuWax option offerings differ in several

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and compare the two data sources. In a very small number of cases (less than 1%) in which the two sources disagree, we verify the correct information directly from the issuer web site (virtually all EuWax issuers maintain web sites containing detailed information regarding their own options).

[9] The EuWax data do not contain information on open interest which is unfortunate since it would allow additional tests of differences in holding periods between investors in the two markets, in the sense that, ceteris paribus, EuWax options should exhibit lower open interest at maturity.

[10] To check for accuracy, we aggregate the EuRex volume data for each underlying and compare them to the volume statistics published in the EuRex annual and monthly reports in EuRex Communications (2002b). In all cases the numbers aggregated from the transactions record are within less than 0.1% of the published number.

[11] While the ratio of trading volume in the two markets exhibits some variation over the months in the sample, there is no discernible trend.

ways. EuWax options are typically long-dated with average maturities of about 450 and 400 days for calls and puts, respectively, while the average maturity for EuRex options is about 150 days. EuWax options are predominantly American style, while index options on EuRex are European style and equity options are American style. There are about five times as many call options (31,116) on EuWax as put options (6,132), while these are always issued in pairs on EuRex. EuWax offers a much larger scope of underlying assets (828 for calls and 431 for puts) compared to EuRex (128 for calls and puts). In addition to domestic blue chip stocks and major indices, which represent the majority of underlying assets on EuRex, underlying assets on EuWax also include a large number of foreign stocks, small-cap and mid-cap stocks, and sub-indices. While not part of the sample, there is also a great variety of interest-rate options and currency options on EuWax. Although the number of different underlying assets on EuRex is smaller, it has almost twice as many different options as EuWax, since it offers many more contracts per underlying asset (264) than EuWax (38 for calls and 14 for puts). EuRex offers both more expiration dates per underlying asset and a larger number of strike prices per expiration date and underlying asset.

3.3. Matching of EuRex and EuWax Options

3.3.1. Option Characteristics

For the subsequent empirical analysis, the sample period is restricted to the year 2000 and to EuRex and EuWax options on six underlying assets: two indices, the German DAX index and the European Dow Jones Euro Stoxx 50 index, and four stocks, Deutsche Bank, Daimler Chrysler, Deutsche Telekom, and Siemens. As a result, the sample consists of 5,411 EuRex options and 4,389 EuWax options. DAX and Euro Stoxx 50 options are the most heavily traded EuRex options during the year 2000, accounting for approximately 46% of EuRex total volume. Options on the four stocks are among the most heavily traded EuRex equity options during the year 2000, accounting for approximately 29% of EuRex total volume. Collectively, options on the selected six underlying assets account for approximately 75% of EuRex total volume. Similarly, EuWax options on the six underlying assets represent a large share of EuWax trading volume. However, not surprisingly given the much larger number of underlying assets on EuWax, the share of EuWax total volume represented by the selected underlying assets is lower at approximately 41%. The volume of the selected EuWax options is approximately 15% of the volume of the selected EuRex options. Comparing the volume of the selected EuWax options to the volume of the selected EuRex options by underlying asset, one observes considerable variation. At the low end, Euro Stoxx 50 and Deutsche Telekom EuWax options account for 1% and 6%, respectively, of their corresponding EuRex options. The percentages are 13%, 14%, and 17% for Daimler Chrysler, Deutsche Bank, and Siemens options, respectively.

Finally, EuWax DAX option volume represents 28% of its EuRex counterpart. The EuWax DAX option market is larger than the three smaller EuRex option markets for Deutsche Bank, Daimler Chrysler and Siemens.

The next step is to match EuRex options with competing EuWax options which provide investors with identical or similar payoff functions. Given that matched options have identical or similar payoff functions, any observed differences should be due to other factors, such as liquidity provision. We create three mutually exclusive categories of matches that differ with respect to the required matching characteristics. All matches have the same underlying asset and option type. Category 1 matches also have the same strike price, expiration date, and exercise style resulting in identical payoff functions for both options. Category 2 matches have the same strike price, and exercise style, but the EuWax expiration date differs by $\pm$ 1 to 7 days from the EuRex expiration date, as small deviations in maturity may be perceived similar by investors given the long average maturity of EuWax options discussed above. Category 3 matches have the same strike price, and the EuWax expiration date may differ by $\pm$ 1 to 7 days from the EuRex expiration date. Furthermore, the exercise style can be different, but the matches are limited to index call options. Category 3 has the following rationale. Index options on EuRex are exclusively European-style options, while index options on EuWax are predominantly although not exclusively American-style options. Since both DAX and Euro Stoxx 50 are total performance indices with reinvestment of dividends, option pricing theory suggests that it is never optimal to exercise American call options early. Thus, American and European index call options should have the same value.

In the matching procedure, a EuRex option can potentially be matched with several EuWax options both because slight variations in option characteristics are allowed in categories 2 and 3, and because there are EuWax options with identical characteristics from different issuers which count as individual matched pairs with their EuRex counterpart. However, we enforce a rule such that each EuWax option is matched with only one EuRex option to achieve the best match quality given by the smallest difference in expiration dates. Table 3 contains summary statistics of the resulting sample of matched options. There are 2,361 matched pairs for 903 unique EuRex options distributed over 199 category 1 matches, 898 category 2 matches, and 1,264 category 3 matches. Not surprisingly, given the general distribution of EuWax options, there are many more call option matches (2,173) than put option matches (188). The number of matches per underlying asset ranges from 221 for Deutsche Bank options to 1,010 for DAX options. For almost all underlying assets and option types, the sample of matches exhibits considerable variation across strike prices and expiration dates. While only approximately 17% of all EuRex options in the sample are matched, they account for 32% of all trading volume among the EuRex options for the six underlying assets, and thus represent 24% of

EuRex total volume. Similarly, the matched EuWax options account for 59% of all trading volume among the EuWax options for the six underlying assets and thus represent 24% of EuWax total volume. The fact that EuWax trading volume is concentrated in EuWax options with a EuRex match also implies that the trading volume of the matched EuWax options represents a larger share of the trading volume of their matching EuRex options than the above mentioned overall (including matching and non-matching options) average of 15%. In fact, the trading volume of matched EuWax options represents 29% of their matched EuRex counterparts.

3.3.2. Option Quotes

For the year 2000, the KKMDB database contains 25,485,590 unique quotes for EuRex options on the six selected underlying assets. The 903 EuRex options with matching EuWax options account for 5,041,031 unique quotes or roughly one-fifth of the total number of quotes. Each of the EuRex quotes is matched with EuWax quotes. Since some EuRex options have multiple EuWax matches, they may have multiple EuWax quote matches as well. For each EuRex quote and corresponding EuWax option, we find the most recent EuWax quote posted prior to the EuWax quote on the same day. Initially, this results in 9,699,923 EuRex-EuWax quote pairs. However, it is frequently the case that the same EuWax quote is matched with several EuRex quotes, because EuRex quotes tend to cluster more in time than EuWax quotes. Therefore only one EuRex-EuWax quote pair is retained such that the time difference between quotes is minimized. This yields 3,294,694 quote pairs.

Next, we introduce several filters to eliminate bad quotes and reduce asynchroneity. We eliminate all quote pairs with a time difference greater than five minutes resulting in 3,163,369 quote pairs, all quote pairs for which either ask quote is zero or smaller than the corresponding bid quote resulting in 3,156,848 quote pairs, and all quote pairs with a difference between the two ask quotes or the two bid quotes greater than 50% of the EuRex quote. This results in 3,062,245 quote pairs. Since match categories 2 and 3 allow for a difference in expiration date between the EuRex option and the matching EuWax option, all observations for which the EuRex option has less than two weeks remaining until maturity are excluded. This ensures that all options included have at least one week remaining until maturity, since EuWax options in match categories 2 and 3 can have up to one week shorter maturity than the corresponding EuRex option. The final sample contains 2,914,515 quote pairs. To compare the two markets, we compute the following measures for each quote pair: the ratio of EuWax ask to EuRex ask (hereafter also referred to as ask ratio), the ratio of EuWax bid to EuRex bid (hereafter also referred to as bid ratio), the EuWax and EuRex percentage bid-ask spreads computed as the ratio of ask and bid difference to ask, and the time difference between the EuWax and the EuRex quote. The number of quote pairs per day varies markedly over the EuRex-EuWax

option matches. Therefore, we compute daily averages of the above measures for each EuRex-EuWax option match. This results in a panel of 95,566 daily observations of EuRex-EuWax option matches.

4. Empirical Evidence

We first provide a detailed univariate comparison of matched EuRex and EuWax options. We then provide multivariate results and robustness checks. Finally, we also give evidence on whether competition from one market improves liquidity (as measured by bid-ask spreads) in the other market.

4.1. Univariate Results for EuRex-EuWax Matches

We group all daily observations by underlying asset, option type (call or put), and match category, forming 22 groups, and then compute averages within each group. The resulting univariate statistics are shown in Table 4. The average time difference over all groups is 59 seconds. Irrespective of underlying asset, option type, or match category a systematic pattern emerges. EuWax ask quotes are higher than EuRex ask quotes by an average of 4.7% over all daily observations. Of the 22 group averages, 20 are significant at the 1% level or better and another one is significant at the 5% level. Among the 21 significant averages, 19 show EuWax ask prices to be higher than EuRex ask prices. The two groups with EuWax ask prices, which are significantly smaller than EuRex ask prices, both have a comparatively small number of daily observations. EuWax bid quotes are on average 9.9% higher than EuRex bid quotes. Of the 22 per group means, 21 are significant at the 1% level or better, and all but one show EuWax bid prices to be higher than EuRex bid prices. For all 19 of the 22 groups, in which both EuWax ask and bid prices are higher than EuRex ask and bid prices, the bid price difference is significantly larger than the ask price difference at the 1% level or better.

The average difference of the bid and ask ratios is 5.2%, which implies that EuWax bid-ask spreads are smaller than EuRex bid-ask spreads. The EuWax bid-ask spreads over all daily observations are 2.8%, which compares fairly closely to the 3.2% reported by Petrella (2001) in a sample of 1,085 Italian bank-issued option quotes. In contrast, the average bid-ask spread is 7.1% for EuRex options. EuWax bid-ask spreads are smaller than EuRex bid-ask spreads in each of the 22 groups with 21 of the bid-ask spread differences significant at the 1% level or better. Since EuWax options tend to have lower trading volume than EuRex options, the results on bid-ask spreads are also consistent with results by Cho and Engle (1999) indicating that the negative empirical relation between volume and bid-ask spreads, which is well supported for primary assets, does not necessarily apply to option markets. It appears that the results are consistent with the idea of differing clienteles suggested in

Section 2. An investor who expects to liquidate his option position before the option's expiration may be willing to pay a higher ask price on EuWax, expecting to benefit from a higher bid price (and thereby smaller round-trip transaction costs) when the option position is liquidated in the future.

Next, we investigate whether the relation indicated by the averages above holds consistently for many quotes. To this end, each of the 95,566 daily observations is categorized based on the relation among the ask and bid quotes. To reduce the number of cases, quote pairs are excluded, in which the comparable bid and/or ask are equal, i.e., the ask ratio (AR) or the bid ratio (BR) is equal to one. This eliminates fewer than 1% of all quote pairs and leaves six cases:

$$\begin{aligned} \text{Case 1} &: \quad BR > AR > 1 \\ \text{Case 2} &: \quad BR > 1 > AR \\ \text{Case 3} &: \quad 1 > BR > AR \\ \text{Case 4} &: \quad AR > BR > 1 \\ \text{Case 5} &: \quad 1 > AR > BR \\ \text{Case 6} &: \quad AR > 1 > BR \end{aligned} \tag{1}$$

For each case, we compute the average ask and bid ratios by underlying asset, option type (call or put), and match category.

Table 5 shows that the full sample results hold consistently across quote pairs as case 1 is the most frequent. Averaged over all underlying assets, types, and match categories, 63% of the quote pairs exhibit higher EuWax ask prices as well as even higher EuWax bid prices. Over the 22 groups, the share of such quote pairs ranges from 11% to 100%. The average ask price difference in this relation is 6%, while the average bid price difference is 12%. Case 1 allows for situations in which EuWax bid prices exceed EuRex ask prices. However, as pointed out previously, investors are unable to arbitrage such cases due to the inability to short EuWax options.

The next largest average share of quote pairs is 27% for case 2, in which the EuWax ask price is lower than the EuRex ask price and the EuWax bid price is higher than the EuRex bid price. This relation (if maintained over the life of the option) would render EuWax options preferable for all investors. Over the 22 groups, the share of such cases ranges from 0% to 54%. In this situation, EuWax ask prices are on average 2% cheaper than EuRex ask prices and EuWax bid prices are on average 5% higher than EuRex bid prices.

Case 3, in which both the EuWax bid and ask quote are smaller than their EuRex counterpart with the ask quote difference being larger, accounts for 8% of quote pairs, on average. Over the 22 groups, the share of this case ranges from 0% to 50%. The EuWax ask price is on average lower

by 8%, while the EuWax bid price is only lower by on average 4%. Thus, all investors would prefer EuWax options, since the savings from the lower ask prices are greater than potential losses from the lower bid prices. Case 3 may include situations in which EuRex bid prices exceed EuWax ask prices for options with identical payoff functions. Ignoring other transaction costs, such situations could constitute potential arbitrage opportunities, as investors are able to write (i.e., short) EuRex options. The potential arbitrage situation occurs in less than 1% of the 2,914,515 quote pairs in the sample and the median difference of the two prices is less than 2.5%. Many of the potential arbitrage quote pairs may be due to asynchroneity, which is confirmed by the fact that the mean time difference is around 3 minutes (as compared to 59 seconds for the entire sample).

Cases 4 and 6 constitute situations in which all investors would prefer EuRex options. These two cases together account for only 1.4% of the observations. Over the 22 groups, their combined share is never larger than 8%. Finally, case 5 is a special case as both EuWax ask and bid prices are lower than on EuRex with the bid price difference being larger. In this situation, an investor expecting early liquidation prefers EuWax options if the savings from the lower ask price are larger than the expected loss from the lower bid price thereby implying an upper, rather than a lower, bound on the likelihood of early liquidation. However, this case is quite rare as it occurs in only 0.5% of the observations.

Overall, the analysis of bid ratios and ask ratios by quote relation confirms the systematic pattern of higher ask and bid prices, and smaller bid-ask spreads on EuWax compared to EuRex. An important caveat applies to the above discussion in the sense that when we speak of investors' preferences for one market or the other, we base the discussion solely on transaction costs derived from quoted bid-ask spreads. As pointed out in Section 2, there are additional factors which we expect to affect an investor's choice between the two markets. Several such additional factors are investigated in the subsequent multivariate analysis.

4.2. Multivariate Results for EuRex-EuWax Matches

4.2.1. Ask Ratios

This section investigates, in a multivariate setting, how the quote competitiveness of EuWax options relative to EuRex options varies in the sample. A natural measure of relative competitiveness is the ratio of ask prices since it affects all option buyers irrespective of the likelihood of early liquidation. Since EuWax options cannot be shorted, the appropriate comparison is for an investor who wants to buy options. While precise data are difficult to obtain, discussions with market participants indicate that EuRex market makers are on average short in options implying that the average EuRex

option investor is also a buyer. For this analysis, the 2,914,515 matched quote pairs described in Section 3.3.1 are used. For each EuWax option in the matched data set, we calculate monthly averages of all variables which results in an unbalanced panel of 8,185 monthly observations for the 2,361 EuWax options with EuRex matches. The multivariate analysis uses monthly averages rather than the previously employed daily averages for two reasons. First, most of the variables used in the subsequent analysis exhibit relatively little time-series variation, which would tend to overstate significance levels in the multivariate analysis. Secondly, employing a lower frequency reduces the problem of potential serial correlation in the ask and bid ratio measures.

Summary statistics for the panel are shown in Table 6. Each monthly observation of ask and bid ratios is based on an average of 355 quotes with a standard deviation of 628 quotes. The average ask ratio is around 1.05, and the average bid ratio is around 1.09. The average number of EuWax options competing with each other and the matching EuRex option is 2.7; the maximum is 8 competing EuWax options. The ratio of EuWax minimum trade size (in units of the underlying asset) to EuRex minimum trade size averages 2.6% with a standard deviation of 5.7% and a maximum of 50%. The guaranteed maximum bid-ask spread in Euros averages 17 cents for EuWax options with a standard deviation of 50 cents. We create a dummy equal to one, if the issuing institution of a EuWax option is also a market maker for the matching EuRex option. This is the case for 59% of all EuRex-EuWax pairs.

We compute the annualized standard deviation of the underlying asset's daily returns during the observation month. Daily return and price information for the underlying assets is obtained from Datastream. The standard deviation averages 32% and ranges from 11% to 77%. For each option pair, we compute daily time to expiration in days using the expiration date of the EuRex option, and moneyness (ratio of underlying asset price to strike price for calls; ratio of strike price to underlying asset price for puts) using the underlying asset's closing price. The daily values are averaged for each observation month. Time to expiration averages 221 days with a standard deviation of 155 days and ranges from 14 days to 730 days. Moneyness averages 102% with a standard deviation of 26% and ranges from 37% to 347%.

Three regression specifications are employed using the EuWax to EuRex ask ratio as the dependent variable. The following variables are present in all specifications: EuWax to EuRex bid ratio, number of competing EuWax options, underlying asset standard deviation, option type (dummy equal to one for puts), moneyness, and time to expiration. As discussed previously, if investors are split between the two markets based on their expected holding periods, the bid ratio should have a positive coefficient, which ought, however, to be smaller than one, given that the average investor's probability of early liquidation is also expected to be smaller than one. The number of competing

EuWax options should have a negative effect on the ask ratio since increased competition should drive down option investors' transaction costs. Standard deviation, option type, moneyness, and time to expiration are used as control variables. In addition to the above variables, specification 1 also contains the EuRex market maker dummy as an explanatory variable. If the EuRex market is one of the venues used by EuWax issuers to hedge their own exposures from selling EuWax options, it could be argued that issuers that are also EuRex market makers in the same underlying asset may enjoy hedging cost advantages. If these hedging cost advantages are passed on to EuWax option buyers, the coefficient of the market maker dummy should be negative.

Specification 2 includes dummy variables for the underlying assets and EuWax issuers. The dummies are designed such that the regular intercept represents DAX EuWax options (the largest EuWax segment) issued by Citibank (the largest EuWax issuer). The market maker dummy is excluded from specification 2, since it is perfectly correlated with the issuer dummy in several cases. Specification 3 adds the EuWax issuer's guaranteed maximum bid-ask spread and the ratio of EuWax to EuRex minimum trade size as explanatory variables to specification 2. Both variables should have negative coefficients. Investors wishing to liquidate early should prefer a lower maximum guaranteed bid-ask spread, since it increases the expected future bid price, ceteris paribus. If EuWax issuers are compensated for this guarantee, they should be able to charge higher ask prices. Similarly, if EuWax investors are on average smaller investors than EuRex investors, they prefer smaller minimum trade sizes, which again allows the EuWax issuer to raise its ask price all else equal. These last two variables are only available for a subset of EuWax options, which reduces the sample to 3,801 monthly observations.

The results of the regressions are shown in Table 7. All standard errors are robust to heteroskedasticity and first-order serial correlation. Since most coefficient estimates are consistent across the three specifications, the discussion is combined. As expected, the coefficient for the bid ratio is positive, less than one at approximately 0.7, and significant, indicating that EuWax option buyers paying higher relative ask prices can expect to be compensated via even higher relative bid prices.[12] The coefficient for the number of competing EuWax options is negative and significant, which is consistent with the idea that competition among EuWax issuers lowers transaction costs for EuWax option buyers. The coefficient for the underlying asset standard deviation is negative and significant. Given that this result also holds in the specifications that include underlying asset dummies, one can interpret this result as an indication that, relative to EuRex options, EuWax liquidity is less affected in periods of higher uncertainty. Time to expiration is negative and significant in the first two spec-

[12] There are potential endogeneity problems using the bid ratio as a regressor. Thus we estimate specification 3 excluding the bid ratio. With the exception of relative minimum trade size, all significant variables from the orginal specification 3 maintain sign and significance.

ifications, but switches sign and becomes insignificant in specification 3. The put dummy coefficient is negative and significant at the 10% level or better in all regressions. Moneyness has a positive coefficient, but is only marginally significant in one specification. Each specification is also run (results not shown) with moneyness and moneyness squared to investigate potential non-linear effects of moneyness, but there are no significant coefficients for the moneyness measures. The market maker dummy coefficient has the predicted negative sign, but is insignificant. On the other hand, both the maximum bid-ask spread and the relative minimum trade size coefficients have negative signs and are significant, lending support to the idea that EuWax issuers can trade off more competitive quotes (lower ask ratios) for other market-making features that are important to the EuWax option buyers.

Relative to DAX options, several other underlying assets have significantly lower ask ratios: Deutsche Bank options and Deutsche Telekom options in specifications 2 and 3, Euro Stoxx 50 options in specification 3 only. Interestingly, there also appears to be considerable variation in ask ratios across issuers relative to the market leader Citibank. BNP Paribas, and Sal. Oppenheim are cheaper in both specifications, while Dresdner Bank, UBS Warburg, and Unicredito Italiano are cheaper in specification 2 only. Credit Lyonnais, Commerzbank, DG Bank, Rabobank, and Societe Generale are more expensive in both specifications, while Merrill Lynch and West LB are more expensive in specification 3 only.[13] Adjusted fit lies between 73% and 75% for the three specifications. On the whole, the results have several interesting implications. For one, competition among issuers benefits investors by driving down EuWax ask prices. Secondly, the evidence supports the notion that liquidity is multi-dimensional in that there is a trade-off between quote competitiveness and other market-making features.

If differences in investors' expected holding periods are one of the factors affecting quoting behavior in the two markets, an additional test can be based on the time-series properties of ask ratios. The idea is that as a particular option approaches maturity, the probability of holding the option to expiration increases and the probability of liquidating before expiration decreases. Therefore, the incentive to pay a higher ask price in the EuWax market decreases, and the ask ratio should decrease over time. While the results in the above regressions are inconclusive with respect to time to expiration, they suffer from the problem that the estimated coefficient measures both cross-sectional as well as time-series variation in time to expiration. To produce a cleaner test of the time-series effects alone, the sample is split by EuRex expiration dates thereby eliminating any cross-sectional variation in time to expiration. To ensure that all time series are available over the full year 2000 sample period, the analysis focuses on options expiring in 2001 and 2002 resulting

[13] A potential explanation of significant issuer dummies could be variation in issuer default risk. However, an analysis (results not shown) of a potential link between issuer dummies and accounting measures of financial strength/leverage/default risk does not reveal any significant results.

in seven different expiration date samples. Two expiration dates are eliminated as their samples contain fewer than 20 monthly observations. The remaining five expiration dates range from March 2001 to June 2002 with sample sizes ranging from 255 to 1,491 observations. We then estimate the above three regression specifications for each of the five expiration date samples. Table 8 shows the estimated coefficients and t-statistics for time to expiration. Estimated coefficients for the remaining variables are not shown but are generally consistent with the previous results. All but one of the 15 coefficients on time to expiration are positive and significant at the 1% level or better. Based on the estimated coefficients, the table also shows the decrease in the ask ratio as the options age by one month. This monthly decrease ranges from 20 to 93 basis points and thus also appears to be economically significant. These results indicate that the mixed evidence on time to expiration in the previous panel regressions may be due to the confounding effect of combining cross-sectional and time-series variation. Once cross-sectional variation is removed, a positive relation between time to expiration and EuWax to EuRex ask ratio is observed, which is consistent with the idea that EuWax and EuRex quotes move closer together as the length of an option pair's potential holding period decreases.

4.2.2. Probability of Early Liquidation

To further explore potential differences between the two markets with respect to investors' holding periods, one can use the observed ask ratios and bid ratios to construct a measure of the implied probability of early liquidation at which investors are divided into EuRex and EuWax clients. The interpretation of this measure is such that all investors with a higher probability than this cut-off value select EuWax, while all investors with a lower probability than this cut-off value select EuRex, assuming that investors choose solely based on expected transaction costs represented by bid-ask spreads. The appendix gives a detailed explanation of the probability of early liquidation cut-off (PELC) measure. We compute daily values of the PELC measure using the daily observations of the ask and bid ratios employed previously. We then take monthly averages of the daily PELC values for each EuRex-EuWax option pair. The average PELC value over all monthly observations is 39% with a standard deviation of 28%. Two measures are employed to assess which options may attract investors with speculative motives who may exhibit higher probabilities of early liquidation as measured by the PELC values. The first measure of speculativeness is the option's omega commonly used by practitioners:

$$Omega = \Delta \times \frac{S}{A^W} \tag{2}$$

where Δ is the option's delta, S is the value of the underlying asset, and A^W is the EuWax ask price. Options with high omegas are attractive to investors with speculative motives since omega measures

the elasticity of option prices with respect to the value of the underlying asset. Therefore, omega measures the return leverage of an option position rather than the price leverage which is measured by the option's delta. The second measure, the vega ratio, is based on the option's vega Λ:

$$VegaRatio = \frac{\Lambda}{A^W} \tag{3}$$

Options with high vegas are attractive to investors with speculative motives regarding the underlying asset's volatility. Similar to the choice of omega rather than delta, we use the ratio of vega to the option's price rather than vega itself. The vega ratio can be interpreted as the option's percentage price change given a one percent change in the underlying asset's standard deviation. For European EuWax options, delta and vega are computed using the option pricing formulas with continuous dividend yields as derived by Merton (1973). For American EuWax options, delta and vega are computed using the analytic approximation as derived by Barone-Adesi and Whaley (1987).[14] Omegas and vega ratios are computed daily and then averaged for each month in the sample. We regress the probability of early liquidation measure (PELC) on both measures of speculativeness using time to expiration and option type as control variables. The results of the regression are shown in Table 9. Adjusted fit for the regression is 23.9%. We observe a positive relation between the PELC measure and time to expiration, which supports the notion that, all else equal, the probability of early liquidation should increase with time to expiration. The coefficient for option type is negative, indicating a lower PELC measure for put options. Both omega and vega ratio have positive significant coefficients, which is consistent with the idea that investors with speculative motives have shorter expected holding periods than investors with hedging motives.

4.3. Robustness

The results suggest that investors with a high probability of early liquidation may be willing to pay higher EuWax ask prices to benefit from lower round-trip transaction costs (as measured by bid-ask spreads) for EuWax options. In the following, we discuss potential alternative explanations for the above findings. In particular, we consider effective vs. quoted spreads, brokerage costs, market-making costs, and liquidity premiums.

4.3.1. Effective Spreads vs. Quoted Spreads

Most of the analysis is based on a comparison of quotes rather than transactions due to the unavailability of large-scale transaction data for EuWax options. While we find significant differences in

[14] For each month in the sample, we use European Central Bank deposit facility rates as the risk-free rate. We employ historic dividend yields of the underlying assets during the year 2000 obtained from OnVista AG. Standard deviations are year 2000 averages of the monthly standard deviations used in the preceeding regressions.

quoted bid-ask spreads between the two markets, it is possible that the same relation is weaker for effective bid-ask spreads if, for example, transactions inside the quoted spread are more frequent on EuRex than on EuWax. The following analysis investigates this issue. A sample of time-stamped transaction prices is provided by the EuWax exchange.[15] We select transaction prices of EuWax options with matching EuRex options as defined previously. Each EuWax transaction is matched with a corresponding EuRex transaction provided that the time difference between the two is less than one hour.[16] Next each transaction is matched with the immediately preceding quote from each respective market such that the quote is no more than ten minutes before the corresponding transaction. We then compute quoted bid-ask spreads as defined previously and effective bid-ask spreads EFF defined as:

$$EFF = \frac{2 \times |P - M|}{A}, \tag{4}$$

where P is the transaction price, M is the average of the corresponding bid and ask quotes, and A is the corresponding ask quote. We also record the share of all transactions taking place inside the spread. As before, we form groups by underlying asset, option type (call or put), and match category, and compute averages which are reported in Table 10. Groups with fewer than ten observations are excluded leaving 1,261 observations in eleven groups.

The results indicate that the incidence of inside-quote transactions is indeed higher on EuRex than on EuWax at 72.2% and 21.3% of all observations, respectively. The more frequent occurrence of inside-quote transactions translates into a larger difference between quoted spreads and effective spreads on EuRex compared to EuWax. Average quoted and effective spreads on EuRex are 8.3% and 4.4%, respectively, while they are 3.6% and 2.6%, respectively, for EuWax. Thus, the difference between bid-ask spreads on EuRex and EuWax shrinks when measured by effective spreads. However, across all groups the difference in effective spreads of 1.8% is significant at the 1% level indicating that EuRex-EuWax differences persist when measured via effective spreads. While the sample of effective spreads is too small to allow a meaningful replication of the multivariate analyses, the fact that economically significant differences in bid-ask spreads persist for effective spreads indicates that the results based on quoted spreads are unlikely to be driven solely by differences in the frequency of inside-quote transactions.

[15] For each day and option, EuWax keeps the last entry in its real-time database in a second database of historic records. Most of the time this last entry is a quote rather than a transaction and thus we cannot use it for the analysis leading to the small sample size compared to the sample of quotes.

[16] Due to the small size of the data set, we are forced to allow a larger time difference than previously employed in order to obtain a reasonable number of observations for the final sample.

4.3.2. Bid-Ask Spreads vs. Brokerage Costs

Another potential reason why investors may be willing to pay higher EuWax ask prices, is that transaction costs unrelated to bid-ask spreads may be lower for EuWax options.[17] To investigate the issue of transaction cost differences unrelated to bid-ask spreads, we perform the following analysis for the German markets using DAX options.[18] Detailed pricing schedules are obtained from three large German on-line brokerages that offer both EuWax and EuRex trading: Comdirect (owned by Commerzbank), Consors (owned by BNP Paribas), and Fimatex (majority owned by Societe Generale). In the case of Consors, the comparison is relatively straightforward as both EuWax and EuRex option trades are charged as a percentage of the transaction value (in addition to a flat charge for each trade). The EuWax charge of 0.25% is half of the EuRex charge of 0.50%. Comdirect and Fimatex charge EuWax options primarily through a percentage (in addition to a flat fee), while EuRex options are charged per contract. Thus, the brokerage cost difference depends on the value of the option.

To generate a range of typical option trade values, we first set the EuWax contract size to 0.01 Euros per index point, which is the most common contract size representing 80% of the EuWax DAX options in the sample of EuRex-EuWax pairs. EuRex DAX options have a contract size of 5 Euros per index point. For each EuWax option with 0.01 Euros contract size, we compute the average ask price over all EuRex-EuWax quote pairs in the sample. Next, we analyze the cross-sectional variation of the ask prices. Over all EuWax options, the mean and median ask price is 7.66 and 4.76 Euros, respectively. In addition, we use the top and bottom decile ask prices of 19.01 and 1.05 Euros, respectively. For each of the four option prices, we compute three trade values corresponding to 1, 10, and 100 EuRex contracts. Finally, we calculate the brokerage costs for each of the resulting twelve trade values under each brokerage's pricing schedule. The results are shown in Table 11. While brokerage costs for EuWax option trades are generally lower than brokerage costs for EuRex options, with the exception of the smallest trade for the lowest-price option, all brokerage cost differences are less than 1% of the trade value. Given that the average difference in the quoted bid-ask spreads between EuRex and EuWax equals more than four times the value of the largest brokerage cost difference, it is unlikely that brokerage cost differences alone could be responsible for the observed differences in bid and ask prices across the two markets.

[17] Horst and Veld (2002) compare brokerage costs for Dutch bank-issued options and option contracts from a derivatives exchange, and find economically significant brokerage cost advantages only in the case of very low-priced ($\leq$ 0.2 Euro) bank-issued options. For bank-issued options with prices of 0.5 Euro or above, the brokerage cost advantage is never larger than 0.9% of the option value, and there are several cases in which traditional option contracts have lower brokerage costs.

[18] A similar analysis (not shown) for the other underlying assets yields comparable results.

4.3.3. Market-Making Costs

It is possible that the differences in bid-ask spreads are driven by differences in the costs of market-making. EuRex market makers can gamma-hedge by offsetting customer purchases with customer writes. EuWax market makers are unable to gamma-hedge since the short-sale restriction prevents customers from writing options. On the other hand, EuWax issuers may be able to hedge their exposures from selling EuWax options by purchasing comparable EuRex options. Furthermore, given that most EuWax issuers are major international banks, it may also be the case that they can sell EuWax options on underlying assets to which they already have an off-setting exposure from some other part of their business. On the whole, it is unclear which of the two markets would provide market makers with hedging cost advantages. However, note that even if EuWax market makers enjoy hedging cost advantages, which may lead to smaller EuWax bid-ask spreads, it does not explain why the smaller bid-ask spreads are not simply symmetric around the option value, but rather exhibit the reported consistent differences between EuRex and EuWax bid and ask prices. Recall also that the market maker dummy in the regression analysis is insignificant which is inconsistent with the idea that EuWax market makers' hedging cost advantages are reflected in their quotes.

Market microstructure theory also suggests that quotes should reflect adverse selection costs. It could be argued that EuWax market makers face little adverse selection costs on the bid side due to the short-sale constraint. Lower adverse selection costs should, ceteris paribus, result in smaller bid-ask spreads driven by higher bid prices on EuWax which is consistent with the empirical findings. However, adverse selection costs cannot explain why ask prices on EuWax should also be higher which is what is observed in the data. Furthermore, Cho and Engle (1999) argue that adverse selection costs should have relatively little impact on option bid-ask spreads compared to bid-ask spreads for primary assets because option market makers can hedge their exposures as explained above. Secondly, the regression results with respect to the probability of early liquidation support the idea that speculators, who are arguably more likely than hedgers to have information advantages, may prefer the EuWax market which should drive up adverse selection costs for EuWax market makers.

4.3.4. Liquidity Premium

Chan and Pinder (2000) study a sample of 252 matched trades of Australian bank-issued equity options and option contracts from a traditional derivatives exchange. They find that bank-issued options have on average higher transaction prices than comparable traditional option contracts and argue that the difference may be due to a liquidity premium for bank-issued options. This liquidity premium is motivated by the fact that Australian bank-issued options in the sample are electronically traded as opposed to floor trading for the derivatives exchange, which Chan and Pinder (2000) argue

leads to faster execution and better transparency for bank-issued options. Furthermore, bank-issued options in their sample tend to have higher trading volumes than comparable option contracts. It is difficult to see how similar arguments of a liquidity premium could be applied to the EuRex-EuWax comparison. While there is no direct evidence on speed of execution, the monthly trading volume of EuWax options is larger than the monthly trading volume of matching EuRex options in only 17% of the observations. Thus, it appears that, if anything, the traditional derivatives exchange is more liquid in our sample which should lead to higher EuRex prices rather than the higher EuWax prices which are observed in the data.

4.4. Options With and Without Competition from the Other Market

While the preceding sections show significant differences between EuRex and EuWax, it is unlikely that the EuRex and EuWax option markets are fully segmented. If investors are willing to switch between the two markets, one would expect that the competitive pressure from the other market will positively affect liquidity relative to options in each market that are not subject to competition from the other market. To investigate this issue, we provide a comparison within each market between bid-ask spreads of options with competition from the other market and bid-ask spreads of options without competition from the other market.

4.4.1. Effect of EuWax Competition on EuRex Bid-Ask Spreads

For each of the 903 EuRex options that have at least one competing EuWax option, we find matching EuRex options that at no point during the sample period have a competing EuWax option. We require that the matching EuRex option has the same underlying asset and type. From the eligible EuRex options without EuWax competition, the one with average daily trading volume closest to the average daily trading volume of the EuRex option (with EuWax competition) is selected each month.[19] Although the previous results indicate that there may not be a strong relation between trading volume and bid-ask spreads, we nonetheless conform to this matching procedure, since it is, for example, used by Mayhew (2002) in the existing literature.

The 2,914,515 quote pairs used in Section 3.3.1 correspond to 1,362,192 unique EuRex quotes.[20] For each of the unique EuRex quotes, we obtain a quote for the matching EuRex option without EuWax competition such that the time difference between the two EuRex quotes is minimized. Next,

[19] Since matches can have differing expiration dates in this analysis, average daily volume is used instead of monthly volume because one of the two options in a match may expire during the observation month. Among EuRex options without EuWax competition, multiple matches with different EuRex options (with EuWax competition) are allowed.

[20] The number of EuRex-EuWax quote pairs is higher, since each EuRex option can be matched with several competing EuWax options.

a filter is introduced to reduce asynchroneity by eliminating all EuRex-EuRex quote pairs with a time difference greater than five minutes. The filtering procedure results in 769,575 quote pairs. As before, we eliminate all quote pairs if at least one of the two options in the pair has less than two weeks until maturity. This reduces the sample to 642,146 pairs. Finally, all pairs are excluded if the average daily trading volume during the sample month differs by more than 20%. The final sample contains 561,578 quote pairs. For each quote pair, we compute the following measures: the percentage bid-ask spread, ratio of the ask price of the EuRex option without EuWax competition to the ask price of the EuRex option with EuWax competition, and time difference. As previously, we then compute daily averages of the above measures for each EuRex-EuRex option match. This results in 19,118 daily observations of EuRex-EuRex option matches. DAX and Euro Stoxx 50 put options are excluded as both have fewer than 50 daily observations. This reduces the number of observations to 19,083.

Finally, we compute averages by underlying asset and option type, forming ten groups. As shown in Table 12, the average time difference between matching quotes is 82 seconds. The ratio of volume for options without EuWax competition to volume for options with EuWax competition is close to one in all groups. The ask price ratio is larger than one in all groups. The latter result may bias us against finding lower bid-ask spreads for EuRex options with EuWax competition since minimum tick sizes create a lower bound on the percentage bid-ask spread of low-priced options. Nonetheless, we find that in six out of ten groups, bid-ask spreads for EuRex options with EuWax competition are significantly (1% level) lower than the bid-ask spreads of their EuRex matches without EuWax competition. Only in one group is the relation significant and reversed. The average bid-ask spread difference over all groups is 1.7% with a maximum of 6.6% for Siemens put options. In general, the results indicate that EuWax competition indeed has a positive effect on the liquidity of EuRex options as measured by bid-ask spreads.

4.4.2. Effect of EuRex Competition on EuWax Bid-Ask Spreads

We also analyze the effect of competition from EuRex on EuWax bid-ask spreads. To this end, for each of the 2,361 EuWax options which have a competing EuRex option, we find matching EuWax options which at no point during the sample period have a competing EuRex option, following the procedure outlined in the previous section. For each of the 2,914,515 unique EuWax quotes used in Section 3.3.1, we obtain a quote for the matching EuWax option without EuRex competition such that the time difference between the two EuWax quotes is minimized. We apply the same filtering procedures and compute daily averages as in the previous section resulting in 53,607 daily observations of EuWax-EuWax matches. DAX, Euro Stoxx 50, and Siemens put options are excluded as they have fewer than 50 daily observations. This reduces the number of observations to 53,509. Next, we compute averages by underlying asset and option type, forming nine groups. As shown

in Table 13, the time difference between quotes is somewhat larger than in the other two matching procedures, but is still close to two minutes at 146 seconds. The ratio of volume for EuWax options without EuRex competition to volume for EuWax options with EuRex competition is close to one in all groups. Similarly, the ask ratio is larger than one in all groups except one, which would again bias us against finding lower bid-ask spreads for EuWax options with EuRex competition.

In four out of nine groups, bid-ask spreads for EuWax options with EuRex competition are significantly (1% level) lower than the bid-ask spreads of their EuWax matches without EuRex competition. While there are also four groups for which the relation is significant (5% level or better) and reversed, the magnitude of the spread differences is considerably larger for the cases that have the expected relation. In the cases in which the EuWax spreads of options with EuRex competition are lower, the difference ranges from 0.8% to 4.9%. On the other hand, the largest difference in the reversed case is only 0.9%. The average bid-ask spread difference across all groups is lower for EuWax options with EuRex competition at 0.6%. As mentioned previously, due to minimum tick sizes the results are biased against finding lower spreads for EuWax options with EuRex competitions, since they are lower-priced on average. Thus, we recompute all tests (results not shown) using only daily observations for which the difference of the ask prices is less than 50% of the ask price for the option with competition. For the price-matched sample, we find that in seven out of eight groups (across underlying asset and type) with more than 50 observations, bid-ask spreads are lower for EuWax options with competition and are significant at the 1% level or better. Thus, while the results are slightly weaker for EuWax options than EuRex options, the evidence is generally supportive of the idea that EuRex competition has a positive effect on the liquidity of EuWax options.

5. Conclusion

Option market structure matters. This paper analyzes two option markets with fundamentally different structures existing side-by-side and competing by offering options with identical or similar characteristics. We provide a comprehensive empirical comparison of bank-issued option markets and traditional derivatives exchanges and show that quotes and the resulting bid-ask spreads differ substantially between the two market types. The EuWax market which has smaller overall volume is shown to have smaller bid-ask spreads indicating that trading volume and bid-ask spreads may be less closely connected in derivatives markets than in primary asset markets. A potential explanation for the co-existence of the two market structures is offered which is based on differences in investors' motives for buying options. Finally, the evidence shows that competition between the two market

types is beneficial to investors in that options with competition from the other market have smaller bid-ask spreads than otherwise comparable options without competition.

The results may be of importance for regulators and practitioners. Current discussions surrounding a pan-European regulatory "securities passport" may consider bank-issued option regulation along the lines of the German model. Similarly, it appears that the creation of bank-issued option markets in the U.S. via less onerous regulation comparable to the European model could help serve option investors with a high probability of early liquidation, and, if nothing else, may improve the quality of existing markets such as the CBOE due to competition. An alternative explanation for the absence of bank-issued option markets in the U.S. is the possibility that traditional U.S. option exchanges serve all investors sufficiently well to eliminate the need for alternative option market structures.

Several avenues for future research remain. For one, other measures of liquidity/market-making quality, such as quoted depth, could be considered for a comparison of the two markets. With respect to quoted depth, one might expect that the EuRex market will be deeper than the EuWax market, since depth is less of a concern for smaller investors using the EuWax market. Bank-issued option markets also allow researchers an indirect look at option demand functions, since issuers are free to choose option characteristics that they expect to have high demand from investors. In particular, issuance can be studied dynamically to investigate how it responds to events in the underlying asset markets (e.g., issuing put options after large underlying asset price drops) and the markets for already existing derivative securities. Similarly, there may be dynamic interaction among issuers and markets with respect to both issuance and market-making behavior. This seems particularly interesting in light of the fact that many bank option issuers are also exchange-issued option market makers in the case of EuRex and EuWax.

Appendix

In this appendix, we formally derive the probability of early liquidation cut-off (PELC) employed in the empirical work. We model the decision of option buyers faced with two option markets exhibiting stylized facts similar to EuRex and EuWax. This section does not provide a full equilibrium analysis of how bid and ask quotes are determined in the two markets. Rather we ask the question as to how an investor would choose if faced with two markets exhibiting the empirically observed bid and ask quote relations.

Consider the problem of an investor who wants to buy a European option and chooses between two markets, R and W, in a two-period discrete-time setup, in which market W does not allow investors to write options. Let A_t^R and B_t^R stand for market R's ask and bid prices at time t, and let A_t^W and B_t^W stand for market W's ask and bid prices at time t, respectively. We assume that all market participants agree on the value of the option V_t which conforms to the following conditions:

$$A_t^R \geq V_t \geq B_t^R \text{ for } t = 0, 1 \tag{1}$$

$$A_t^W \geq Max\left[V_t, B_t^W\right] \text{ for } t = 0, 1 \tag{2}$$

$$A_t^R = A_t^W = V_t = I_t = B_t^R = B_t^W \text{ for } t = T = 2, \tag{3}$$

where T is the option's expiration date, and I_t is the option's intrinsic value. Equation (1) states that in market R, which does not have a short-sale restriction, investors cannot sell the option for more than its true value nor buy the option for less than its true value. Only the latter condition holds in market W as stated in equation (2). On the other hand, in market W we allow cases in which bid prices may be higher than the option's value as investors cannot exploit this apparent mispricing due to the short-sale constraint. The third condition reflects that the option is worth its intrinsic value at expiration. The subsequent analysis is also valid for American options if we impose the additional assumption that all bid prices will be higher than the intrinsic value before maturity.

The first two conditions together imply a no-arbitrage condition between the two markets:

$$A_t^W \geq Max\left[V_t, B_t^W\right] \geq V_t \geq B_t^R \text{ for } t = 0, 1. \tag{4}$$

Ask prices in market W cannot be less than bid prices in market R, as this would give rise to an arbitrage opportunity in which investors could write an option in market R resulting in proceeds of B^R and hedge the resulting exposure by buying an option in market W at a cost of A^W. On the other hand, a comparable no-arbitrage condition does not exist in the other direction in the sense that ask prices in market R can be less than bid prices in market W. Investors cannot exploit such a situation as it would require writing options in market W, which is not allowed.

Now consider the problem of an investor who has probability P of liquidating the option position at time $t = 1$. The expected transaction costs (arising from bid-ask spreads) $E_0[C]$ of options from the two markets can be written as follows, respectively:

$$\begin{aligned} E_0\left[C^R\right] &= A_0^R - V_0 + P \times \frac{E_0\left[V_1 - B_1^R\right]}{1+r} \\ E_0\left[C^W\right] &= A_0^W - V_0 + P \times \frac{E_0\left[V_1 - B_1^W\right]}{1+r}, \end{aligned} \tag{5}$$

where r is a discount rate used to obtain the present value of future transaction costs. The investor is indifferent between the two options for $E_0\left[C^R\right] = E_0\left[C^W\right]$. This condition can be rewritten as follows:

$$A_0^W - A_0^R = P \times \frac{E_0\left[B_1^W - B_1^R\right]}{1+r}. \tag{6}$$

At time $t = 0$, an option investor who knows with certainty that the option will be held until maturity should always purchase the option with the cheaper ask price. If $P = 0$ for all investors, and if one ask price is consistently lower than the other, the non-preferred market will eventually vanish or should not exist at all. The problem is also trivial (choose the option with the lower ask price today) for the case in which the option with the lower ask price today is also expected to have higher bid prices in the future. Again, if this condition holds consistently, the non-preferred market should not exist.

A more interesting case occurs if one market consistently exhibits higher ask prices and higher bid prices. In this case, an investor with a positive probability of early liquidation may choose an option with a higher ask price today if he expects that the option will also have a higher bid price in the future when the option position is liquidated. Rearranging (6) gives a minimum probability P^* of early liquidation required for the investor to choose the higher-priced option today:

$$P^* = \frac{\left(A_0^W - A_0^R\right)(1+r)}{E_0\left[B_1^W - B_1^R\right]}. \tag{7}$$

P^* divides option buyers into two clienteles. Option buyers with $P < P^*$ buy options in the market exhibiting lower ask prices, while option buyers with $P > P^*$ buy options in the market exhibiting higher ask prices. Equation (7) also shows that the expected future bid price difference should be higher than today's ask price difference. This implication is due to two effects. First, the future bid price difference is reduced by the time value of money. Secondly, the expected bid price difference is earned only with probability P, which may be smaller than one, while the ask price difference is incurred with certainty if the more expensive option is purchased today.

To implement an empirical measure of P^*, we use the observed ask ratios and bid ratios to construct a measure of the implied probability of early liquidation at which investors are divided into EuRex and EuWax clients. The empirical measure makes two simplifications in that it ignores

the effect of the time value of money by setting $r = 0$. Furthermore, it uses the current bid ratio as a measure of the investor's expected bid ratio. The interpretation of the resulting measure is such that all investors with a higher probability than this cut-off value select EuWax, while all investors with a lower probability than this cut-off value select EuRex. We construct the probability of early liquidation cut-off (PELC) as follows.

$$PELC = \begin{cases} \frac{AR-1}{BR-1}\frac{A^R}{B^R} & \text{Case 1: } BR > AR > 1 \\ 0 & \text{Case 2: } BR > 1 > AR \\ 0 & \text{Case 3: } 1 > BR > AR \\ 1 & \text{Case 4: } AR > BR > 1 \\ \text{Not defined} & \text{Case 5: } 1 > AR > BR \\ 1 & \text{Case 6: } AR > 1 > BR \end{cases} \tag{8}$$

where AR is the ratio of EuWax ask to EuRex ask and BR is the ratio of EuWax bid to EuRex bid. Cases 1 through 6 above correspond directly to cases 1 through 6 reported in the univariate results in Table 5.[21] As shown in the univariate results, the first case in the above equation is by far the most frequent, whereby EuWax ask and bid prices are higher with the bid price difference being larger than the ask price difference. Under the above assumptions, the expression for the first case is equivalent to the theoretical result in equation (7). Cases 2 and 3 (cases 4 and 6) are situations in which all investors irrespective of their probability of early liquidation prefer EuWax (EuRex) and we set the cut-off value to zero (one). Case 5 has both lower bid and ask prices on EuWax. In this situation investors, initially save money by buying EuWax options, but may loose even more money later on if the option is liquidated. However, the initial savings are certain while the losses are only incurred with the probability of early liquidation. Unlike case 1, it would be investors with a probability of early liquidation below rather than above a certain threshold who prefer EuWax in this last case. We exclude this case from the empirical analysis as it is unclear how to combine its PELC measure with the other cases. The excluded case represents fewer than .5% of the monthly observations.

[21] As in the univariate analysis, we exclude situations where either ratio equals one.

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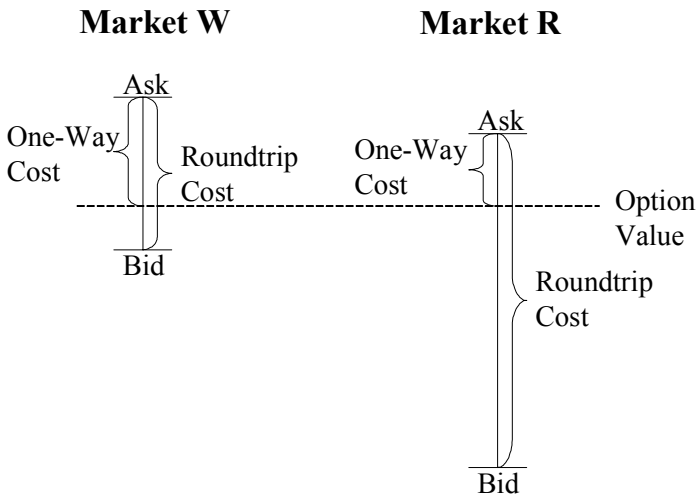

Figure 1. One-Way vs. Round-Trip Transaction Costs

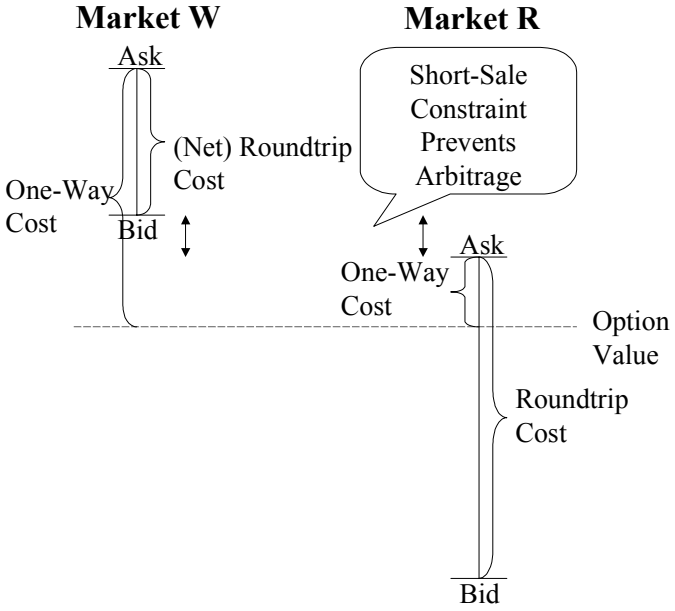

Figure 2. One-Way vs. Round-Trip Transaction Costs with Short-Sale Constraint in Market W

Table 1: Institutional Differences between EuRex and EuWax

The table shows institutional differences between the EuRex and EuWax option markets.

Feature	EuRex	EuWax
Counterparty	Central	Different Issuers
Market-Making	Several Competing Market Makers	Issuer as Predominant Market Maker
Shorting	Possible	Not Possible
Market-Making Guarantees (e.g., trade size, depth)	Same for All Market Makers	Vary by Issuer
Contract Design	Standardized	Chosen by Issuer
Creation of New Contracts	Governed by Rules	At Issuer's Discretion

Table 2: Market Activity in the EuRex and EuWax Option Markets

The table shows the number of EuRex market makers/EuWax issuers, underlying assets, average time to expiration (in days), and the mean, median, and standard deviation of the number of option contracts for EuWax and EuRex options during the period from May 1, 1999, to October 31, 2001. Contract numbers are shown by option type, issuer, underlying asset, and expiration date. Data on option characteristics are from EuWax, EuRex, and OnVista.

		EuRex		EuWax	
		Call	Put	Call	Put
Market Makers / Issuers		42	42	23	20
Underlying Assets		128	128	828	431
Underlying Assets per Market Maker / Issuer	Mean	28	28	142	67
	Median	16	16	132	44
	St. Dev.	30	30	110	55
Option Contracts	American	28,434	28,431	30,724	6,064
	European	5,356	5,356	392	68
	Total	33,790	33,787	31,116	6,132
Option Contracts per Issuer	Mean			1,353	307
	Median			1,214	299
	St. Dev.			1,173	265
Option Contracts per Underlying Asset	Mean	264	264	38	14
	Median	224	224	8	3
	St. Dev.	222	222	94	51
Expiration Dates per Underlying Asset	Mean	18.5	18.5	10.9	6.2
	Median	20.5	20.5	4.0	3.0
	St. Dev.	7.8	7.8	17.2	9.5
Expiration Dates per Underlying Asset, Issuer	Mean			3.2	2.2
	Median			2.0	2.0
	St. Dev.			2.7	1.5
Time to Expiration (in days)	Mean	152	152	453	409
	Median	88	88	455	416
	St. Dev.	153	153	154	159
Strike Prices per Underlying, Expiration Date, Issuer	Mean	14.3	14.3	3.2	2.1
	Median	10.0	10.0	2.0	1.0
	St. Dev.	12.2	12.2	3.1	2.7

Table 3: Summary Statistics for Competing EuRex and EuWax Options

The table shows the number of observations, absolute value of expiration date difference, annual trading volume (in million Euro million paid premia), strike price (mean, standard deviation, minimum, maximum), time to expiration of the EuRex option in days (mean, minimum, maximum), contract size, EuWax minimum trade size, and ratio of EuWax and EuRex trade size for a sample of matched pairs of EuRex and EuWax options during the year 2000. Match category 1 has the same underlying asset, type, strike price, expiration date, style. Category 2 is as catetgory 1 except ± 7 days expiration date difference. Category 3 is as category 2 except difference in style is allowed for index call options. All numbers are means unless indicated otherwise. Underlying assets are: Deutsche Bank, Daimler Chrysler, Deutsche Telekom, DAX index, Dow Jones Euro Stoxx 50 index, and Siemens. Simple and observation-weighted averages are shown in the last two columns. Data on option characteristics and volume are from EuWax, EuRex, and OnVista.

		Deutsche Bank		Daimler Chrysler		Deutsche Telekom		Siemens		DAX		Euro Stoxx 50		All	Weighted
		Call	Put	Call	Put	Call	Put	Call	Put	Call	Put	Call	Put		
Observations	Total	191	30	189	47	224	44	280	48	1,010	4	279	15	2,361	
	Category 1	28	4	22	8	38	3	45	7	4	4	21	15	199	
	Category 2	163	26	167	39	186	41	235	41					898	
	Category 3									1,006		258		1,264	
	Exp. Date Difference	3.4	3.2	3.4	3.0	3.6	3.3	3.6	3.2	2.4	0	1.7	0	2.6	2.8
	EuRex Volume	1,419	194	445	441	1,502	487	1,310	153	7,307	14	5,261	581	1,593	4,223
	EuWax Volume	108	4	340	5	264	37	521	17	4,059	64	60	0	456	1,867
Strike	Mean	93	81	73	69	60	53	142	116	7,143	7,100	4,842	4,373	2,012	
	Standard Deviation	17	12	18	17	24	15	40	35	1,125	115	900	555	239	
	Mininum	50	60	40	40	26	26	60	60	4,000	7,000	3,000	3,200	1,464	
	Maximum	140	100	120	100	140	80	250	180	10,000	7,200	7,000	7,000	2,526	
Time to	Mean	240	267	266	208	262	207	230	254	165	315	184	318	243	203
Expiration	Minimum	14	49	14	14	14	14	14	14	14	268	14	275	14	14
	Maximum	730	730	730	676	721	697	730	730	718	367	704	420	730	730
	EuRex Contract Size	100	100	100	100	100	100	100	100	5	5	10	10	69	48
	EuWax Contract Size	.21	.19	.18	.16	.25	.34	.24	.13	.01	.01	.01	.01	.14	.10
	EuWax Trade Size	24	33	29	29	33	43	36	31	37	1	53	80	36	37
	Relative Size	5%	6%	5%	5%	8%	15%	9%	4%	7%	0%	3%	7%	6%	6%

Table 4: Univariate Results for Matched EuRex and EuWax Options

The table shows the type (call or put), underlying asset (Deutsche Bank, Daimler Chrysler, Deutsche Telekom, DAX index, Dow Jones Euro Stoxx 50 index, and Siemens), match category, number of daily observations, number of quote pairs, average time difference, average ratio of ask prices, average ratio of bid prices, implied early liquidation probability, and average bid-ask spread (ratio of (ask minus bid) to ask) for a sample of matched quote pairs of EuRex and EuWax options during the year 2000. Match category 1 has the same underlying asset, type, strike price, expiration date, style. Category 2 is as category 1 except ± 7 days expiration date difference. Category 3 is as category 2 except difference in style is allowed for index call options. The match categories are mutually exclusive. Averages are calculated by first computing daily averages of observed quotes for each EuRex-EuWax option pair. The daily observations are then averaged by underlying asset, type, and match category. T-tests are computed for ask ratio (different from 1), bid ratio (different from 1), difference of ask ratio and bid ratio (different from 0), and the difference of the bid-ask spreads (different from 0). Insignificant t-tests (p-value > 5%) are indicated with #. Simple and daily-observation-weighted averages of all measures are computed across all options in the sample. Data on option characteristics are from EuWax, EuRex, and OnVista. Quote data are from EuWax and KKMDB.

Underlying	Type	Match	Daily	Quote	Time	EuWax / EuRex		Diff.	BA Spread	
Asset		Cat.	Obs.	Pairs	Diff.	Ask	Bid	t-Stat.	EuRex	EuWax
Deutsche	Call	1	1,075	28,952	1:20	1.061	1.133	14.7	10.6%	4.86%
Bank		2	7,979	196,781	1:13	1.021	1.086	49.1	8.2%	2.5%
	Put	1	27	401	1:33	1.065	1.104	2.2	#12.4%	#9.0%
		2	1,122	12,174	1:32	1.033	1.108	16.0	12.6%	6.2%
Daimler	Call	1	583	7,054	1:29	1.080	1.142	7.5	15.3%	10.5%
Chrysler		2	7,219	76,358	1:35	1.090	1.164	31.8	13.8%	8.1%
	Put	1	162	2,818	1:15	#.998	1.050	6.2	9.4%	4.8%
		2	2,790	26,874	1:28	1.043	1.103	24.8	7.3%	2.2%
Deutsche	Call	1	1,291	33,894	1:18	1.068	1.152	18.1	13.7%	7.0%
Telekom		2	8,044	164,835	1:16	1.040	1.119	42.2	12.5%	6.2%
	Put	1	46	1,915	1:06	1.013	1.055	4.6	9.3%	5.5%
		2	2,857	111,250	1:04	1.020	1.077	27.5	7.3%	2.3%
DAX	Call	1	63	201	0:50	1.023	1.074	6.4	5.0%	.3%
		3	43,069	1,903,803	0:39	1.050	1.090	66.8	4.6%	1.1%
	Put	1	47	303	0:38	1.020	1.048	2.7	2.9%	.2%
Euro	Call	1	79	1,609	1:09	.975	#1.005	2.6	6.0%	3.2%
Stoxx 50		3	7,500	212,871	1:08	1.050	1.088	29.4	6.5%	3.1%
	Put	1	55	1,363	0:58	.962	.982	2.3	4.8%	2.8%
Siemens	Call	1	943	14,815	1:15	1.018	1.068	12.9	8.0%	3.8%
		2	9,399	103,898	1:09	1.037	1.084	34.9	6.1%	2.1%
	Put	1	45	1,099	1:22	1.047	1.126	6.6	9.3%	2.6%
		2	1,171	11,247	1:20	1.054	1.104	12.7	7.5%	3.2%
All			95,566	2,914,515	1:13	1.035	1.089		8.8%	4.2%
All (Weighted)			95,566	2,914,515	0:59	1.047	1.099		7.1%	2.8%

Table 5: Univariate Results for Matched EuRex and EuWax Options by Quote Relation

The table shows the type (call or put), underlying asset (Deutsche Bank, Daimler Chrysler, Deutsche Telekom, DAX index, Dow Jones Euro Stoxx 50 index, and Siemens), match category, share of observations (in %), average ratio of ask prices (AR), average ratio of bid prices (BR), for a sample of matched quote pairs of EuRex and EuWax options during the year 2000. Match category 1 has the same underlying asset, type, strike price, expiration date, style. Category 2 is as category 1 except ± 7 days expiration date difference. Category 3 is as category 2 except difference in style is allowed for index call options. The match categories are mutually exclusive. Quote pairs are categorized into six groups according to the ratio of ask prices and the ratio of bid prices (observations with either ratio equal one are excluded). Averages of all observed quote pairs are computed across underlying, type, match category, and ratio category. Data on option characteristics are from EuWax, EuRex, and OnVista. Quote data are from EuWax and KKMDB.

			Case 1 $BR > AR > 1$			Case 2 $BR > 1 > AR$			Case 3 $1 > BR > AR$			Case 4 $AR > BR > 1$			Case 5 $1 > AR > BR$			Case 6 $AR > 1 > BR$		
Under-lying	Type	Match Cat.	%	Ask Ratio	Bid Ratio	%	Ask Ratio	Bid Ratio	%	Ask Ratio	Bid Ratio	%	Ask Ratio	Bid Ratio	%	Ask Ratio	Bid Ratio	%	Ask Ratio	Bid Ratio
Deutsche Bank	Call	1	67	1.09	1.17	29	0.97	1.04	1	0.95	0.97	1	1.17	1.14	1	0.91	0.83	0	1.05	0.95
		2	52	1.06	1.14	42	0.98	1.04	6	0.93	0.97	0	1.14	1.12	1	0.83	0.80	0	1.02	0.97
	Put	1	100	1.04	1.11	0			0			0			0			0		
		2	62	1.07	1.15	31	0.97	1.06	6	0.87	0.93	1	1.14	1.11	0	0.92	0.90	0	1.06	0.96
Daimler Chrysler	Call	1	80	1.10	1.19	19	0.90	1.14	0			1	1.13	1.11	1	0.78	0.67	0		
		2	74	1.09	1.17	20	0.96	1.09	3	0.88	0.95	2	1.17	1.13	1	0.88	0.84	0	1.04	0.98
	Put	1	37	1.03	1.08	54	0.98	1.03	8	0.82	0.84	1	1.04	1.03	0			0		
		2	63	1.06	1.11	32	0.98	1.03	4	0.88	0.91	0	1.08	1.07	1	0.93	0.92	0	1.02	0.97
Deutsche Telekom	Call	1	67	1.10	1.20	21	0.96	1.08	5	0.90	0.95	4	1.19	1.11	1	0.96	0.91	1	1.09	0.91
		2	60	1.09	1.18	28	0.96	1.07	8	0.91	0.96	2	1.12	1.09	1	0.88	0.82	1	1.09	0.89
	Put	1	52	1.04	1.09	43	0.98	1.02	4	0.96	1.00	0			0			0		
		2	46	1.04	1.11	48	0.98	1.04	6	0.97	0.99	0	1.15	1.14	0	0.98	0.97	0	1.00	0.99
DAX	Call	1	65	1.05	1.10	30	0.98	1.04	5	0.95	0.98	0			0			0		
		3	82	1.06	1.11	16	0.99	1.02	2	0.97	0.98	0	1.25	1.19	0	0.91	0.85	0	1.19	0.89
	Put	1	65	1.04	1.07	28	0.99	1.01	7	0.96	0.99	0			0			0		
Euro Stoxx 50	Call	1	54	1.02	1.06	9	1.00	1.02	33	0.91	0.93	0			4	0.84	0.83	0		
		3	78	1.06	1.10	14	0.99	1.03	4	0.96	0.98	3	1.23	1.17	0	0.91	0.86	0	1.09	0.92
	Put	1	11	1.01	1.03	39	0.99	1.01	50	0.94	0.95	0			0			0		
Siemens	Call	1	48	1.07	1.12	31	0.97	1.04	12	0.92	0.96	7	1.11	1.09	1	0.90	0.82	0		
		2	63	1.07	1.12	29	0.98	1.03	6	0.94	0.96	1	1.11	1.07	1	0.93	0.90	1	1.04	0.94
	Put	1	89	1.05	1.12	11	0.99	1.09	0			0			0			0		
		2	72	1.08	1.13	21	0.98	1.04	4	0.95	0.98	1	1.16	1.09	1	0.88	0.84	1	1.09	0.92
Average			63	1.06	1.12	27	0.98	1.05	7.7	0.92	0.96	1.2	1.15	1.11	0.5	0.89	0.85	0.2	1.06	0.94

Table 6: Summary Statistics for Multivariate Analysis of Matched EuRex and EuWax Options

The table shows sample mean, standard deviation, minimum, and maximum of quotes per month, match category, absolute value of expiration date difference, ratio of ask prices, ratio of bid prices, number of competing EuWax options, ratio of minimum trade size, EuWax maximum bid-ask spread (in Euros), a dummy equal to one for EuWax issuer being a EuRex Market-Maker for the same underlying asset, annualized standard deviation of underlying asset returns during the observation month, time to expiration (in days) of the EuRex option, and moneyness. The sample contains matched quote pairs of EuRex and EuWax options on the following underlying assets: Deutsche Bank, Daimler Chrysler, Deutsche Telekom, DAX index, Dow Jones Euro Stoxx 50 index, and Siemens. Match category 1 has the same underlying asset, type, strike price, expiration date, style. Category 2 is as category 1 except ± 7 days expiration date difference. Category 3 is as category 2 except difference in style is allowed for index call options. The match categories are mutually exclusive. Number of observations is shown by option type and underlying asset. For the ask and bid ratios, monthly averages are calculated from all observed quotes during the observation month for each EuRex-EuWax option pair. For time to expiration and moneyness, data are calculated daily and then averaged across all observations during the month. Data on option characteristics are from EuWax, EuRex, and OnVista. Quote data are from EuWax and KKMDB. Daily data on underlying asset returns and prices are from Datastream. All data is monthly. Sample period is the year 2000.

Panel A: Descriptive Statistics of Variables

	Mean	Standard Deviation	Minimum	Maximum
Quotes / Month	355	628	1	6,666
Match Category	2.5	0.6	1	3
Abs (Expiration Date Difference)	3.1	2.3	0	7
EuWax Ask / EuRex Ask	1.05	0.09	0.56	1.48
EuWax Bid / EuRex Bid	1.09	0.11	0.54	1.50
# Competing EuWax Options	2.7	1.6	1	8
Minimum Trade Size: EuWax / EuRex	2.6%	5.7%	0.0%	50.0%
EuWax Maximum Euro Spread	0.17	0.50	0.02	5
EuWax Issuer = EuRex Market Maker (=1)	0.59	0.49	0	1
Underlying Asset Standard Deviation	32%	14%	11%	77%
Time to Expiration	221	155	14	730
Moneyness	102%	26%	37%	347%

Panel B: Sample Size

	Observations
Total	8,185
- Calls	7,511
- Puts	674
- Deutsche Bank	808
- Daimler Chrysler	892
- Deutsche Telekom	931
- DAX	3,444
- Euro Stoxx 50	915
- Siemens	1,195

Table 7: Multivariate Results for Matched EuRex and EuWax Options

The table shows the coefficient estimate, t-statistic, number of observations, and adjusted fit for regressions of the ratio of ask prices on the ratio of bid prices, number of competing EuWax options, annualized standard deviation of underlying asset returns during the observation month, option type, time to expiration (in days) of the EuRex option, moneyness, a dummy (=1 for EuWax issuer being a EuRex Market-Maker for the matched option), EuWax maximum bid-ask spread (in Euros), ratio of minimum trade size, underlying asset dummies, and issuer dummies. The sample contains matched quote pairs of EuRex and EuWax options on the following underlying assets: Deutsche Bank, Daimler Chrysler, Deutsche Telekom, DAX index, Dow Jones Euro Stoxx 50 index, Siemens. Match category 1 has the same underlying asset, type, strike, exp. date, style. Category 2 is as category 1 except ± 7 days exp. date difference. Category 3 is as category 2 except difference in style is allowed for index call options. The match categories are mutually exclusive. For the ask and bid ratios, monthly averages are calculated from all quotes during the observation month for each EuRex-EuWax pair. For time to expiration and moneyness, data are calculated daily and averaged over all observations during the month. Data on option characteristics are from EuWax, EuRex, and OnVista. Quote data are from EuWax, KKMDB. Daily data on underlying asset returns and prices are from Datastream. Standard errors are robust to heteroskedasticity and first-order serial correlation. All data is monthly. Sample period is the year 2000.

	Spec. 1		Spec. 2		Spec. 3	
Variable	Coeff.	t-Stat.	Coeff.	t-Stat.	Coeff.	t-Stat.
Intercept	.32	22.7	.32	21.1	.31	12.4
EuWax Bid / EuRex Bid	.69	37.1	.68	36.3	.69	22.8
# Competing EuWax Options	-.0027	-7.5	-.0027	-7.3	-.0048	-7.7
Underlying Asset Standard Deviation	-.043	-10.8	-.030	-4.3	-.047	-4.9
Type (Put = 1)	-.0085	-3.6	-.0047	-1.7	-.0086	-3.2
Time to Expiration	-2.4E-05	-4.8	-1.9E-05	-3.6	9.0E-06	1.1
Moneyness	.0055	0.6	.014	1.7	.0015	0.1
EuWax Issuer = EuRex Market Maker (=1)	-.00029	-0.2				
EuWax Maximum Euro Spread					-.0059	-3.8
Minimum Trade Size: EuWax / EuRex					-.12	-4.6
Deutsche Bank			-.019	-10.6	-.014	-6.0
Daimler Chrysler			-.0031	-0.9	-.0051	-1.2
Deutsche Telekom			-1.2E-02	-3.5	-.0076	-2.0
Euro Stoxx 50			-5.0E-05	0.0	-.015	-4.9
Siemens			.0028	1.2	.0033	1.2
Banque Nationale de Paris Paribas			-.0098	-2.8	-.011	-3.1
Credit Lyonnais			.028	2.5	.057	4.1
Commerzbank			.0071	3.2	.0074	2.0
Deutsche Bank			.00088	0.5	.0023	1.0
DG Bank			.0040	2.2	.024	5.7
Dresdner Bank			-.0069	-2.0	-.0043	-1.2
Goldman Sachs			-.0013	-0.2	-.00062	-0.1
HypoVereinsBank			-.00058	-0.2	.0063	1.5
Lehman Brothers			-.0076	-1.1	.0062	0.8
Merrill Lynch			.0059	0.6	.019	1.9
RaboBank			.034	3.7	.027	4.9
Societe Generale			.0075	3.7	.029	7.3
Sal. Oppenheim			-.023	-7.2	-.025	-6.1
HSBC Trinkaus Burkhardt			-.0023	-1.3	-.0023	-0.8
UBS Warburg			-.0063	-2.2	.0045	0.9
Unicredito Italiano			-.018	-3.1	.0049	0.8
Westdeutsche Landesbank			-.0070	-1.2	.021	2.8
Observations	8,185		8,185		3,801	
Adj. R^2	73.1%		74.8%		74.8%	

Table 8: Time-Series Variation in Ask Ratios

The table shows the time to expiration coefficient estimate and t-statistic, estimated effect of a 1-month change in time to expiration on ask ratios, and number of observations for regressions of the ratio of ask prices on the ratio of bid prices, number of competing EuWax options, annualized standard deviation of underlying asset returns during the observation month, option type, time to expiration (in days) of the EuRex option, moneyness, a dummy (=1 for EuWax issuer being a EuRex Market-Maker for the matched option), EuWax maximum bid-ask spread (in Euros), ratio of minimum trade size, underlying asset dummies, and issuer dummies. The sample contains matched quote pairs of EuRex and EuWax options on the following underlying assets: Deutsche Bank, Daimler Chrysler, Deutsche Telekom, DAX index, Dow Jones Euro Stoxx 50 index, Siemens. Match category 1 has the same underlying asset, type, strike, exp. date, style. Category 2 is as category 1 except ± 7 days exp. date difference. Category 3 is as category 2 except difference in style is allowed for index call options. The match categories are mutually exclusive. For the ask and bid ratios, monthly averages are calculated from all quotes during the observation month for each EuRex-EuWax pair. For time to expiration and moneyness, data are calculated daily, and averaged over all observations during the month. The sample is split by EuRex expiration dates. Data on option characteristics are from EuWax, EuRex, and OnVista. Quote data are from EuWax, KKMDB. Daily data on underlying asset returns and prices are from Datastream. Standard errors are robust to heteroskedasticity and first-order serial correlation. All data is monthly. Sample period is the year 2000.

EuRex Expiration Date		Specification 1	2	3
March 16, 2001	Time to Expiration	1.1E-04	9.8E-05	1.1E-04
	t-Statistic	2.1	3.8	3.7
	1-Month Effect	0.34%	0.30%	0.34%
	Observations	909	909	909
June 15, 2001	Time to Expiration	7.1E-05	6.7E-05	6.9E-05
	t-Statistic	5.7	5.5	5.4
	1-Month Effect	0.21%	0.20%	0.21%
	Observations	1,491	1,491	1,482
September 21, 2001	Time to Expiration	1.6E-04	1.7E-04	1.7E-04
	t-Statistic	3.5	3.0	3.9
	1-Month Effect	0.48%	0.50%	0.51%
	Observations	418	418	408
December 21, 2001	Time to Expiration	9.8E-05	9.0E-05	9.6E-05
	t-Statistic	4.0	4.5	3.9
	1-Month Effect	0.29%	0.27%	0.29%
	Observations	759	759	747
June 21, 2002	Time to Expiration	3.1E-04	3.1E-04	3.0E-04
	t-Statistic	3.8	4.1	3.8
	1-Month Effect	0.92%	0.93%	0.90%
	Observations	255	255	255

Table 9: Probability of Early Liquidation

The table shows the coefficient estimate, t-statistic, mean, standard deviation, minimum, maximum, number of observations, and adjusted fit for a regression of probability of early liquidation cut-off (PELC) on the option omega, ratio of option vega to EuWax ask, option type, time to expiration (in days) of the EuWax option. The sample contains matched quote pairs of EuRex and EuWax options on the following underlying assets: Deutsche Bank, Daimler Chrysler, Deutsche Telekom, DAX index, Dow Jones Euro Stoxx 50 index, Siemens. Match category 1 has the same underlying asset, type, strike, exp. date, style. Category 2 is as category 1 except ± 7 days exp. date difference. Category 3 is as category 2 except difference in style is allowed for index call options. The match categories are mutually exclusive. PELC is computed from ask ratios and bid ratios. Omega is computed as delta times the ratio of the value of the underlying asset to the EuWax ask price. Omega, vega, time to expiration, underlying asset value, and EuWax ask price are calculated daily and averaged over all observations during the month. Data on option characteristics and volume are from EuWax, EuRex, and OnVista. Quote data are from EuWax, KKMDB. Daily data on underlying asset returns and prices are from Datastream. Standard errors are robust to heteroskedasticity and first-order serial correlation. All data is monthly. Sample period is the year 2000.

Variable	Coefficient	t-Statistic	Mean	Standard Deviation	Minimum	Maximum
Intercept	.164	17.7				
Omega	.007	6.2	6.9	6.3	.8	80.1
Vega / EuWax Ask	1.842	14.3	.038	.047	0	.527
Type (Put = 1)	-0.033	-2.8	0.08	0.27	0	1
Time to Expiration	4.9E-04	20.1	224	156	14	730
Observations	7,775					
Adj. R^2	23.9%					

Table 10: Effective Spreads for Matched EuRex and EuWax Options

The table shows the type (call or put), underlying asset (Deutsche Bank, Daimler Chrysler, Deutsche Telekom, DAX index, Dow Jones Euro Stoxx 50 index, and Siemens), match category, number of observations, average time difference, average quoted bid-ask spread (ratio of (ask minus bid) to ask), average effective bid-ask spread (ratio of absolute difference between transaction price and mid quote to ask price times two), and share of inside-the-quote transaction prices for a sample of matched quote/transaction pairs of EuRex and EuWax options during the year 2000. Match category 1 has the same underlying asset, type, strike price, expiration date, style. Category 2 is as category 1 except ± 7 days expiration date difference. Category 3 is as category 2 except difference in style is allowed for index call options. The match categories are mutually exclusive. Simple and daily-observation-weighted averages of all measures are computed across all options in the sample. Data on option characteristics are from EuWax, EuRex, and OnVista. Quote and transaction data are from EuRex, EuWax and KKMDB.

Under-lying	Type	Match Cat.	Obs.	Time Difference			Spread				Share of Inside Trans.	
				Trans-actions	Trans./Quote		Quoted		Effective			
					EuRex	EuWax	EuRex	EuWax	EuRex	EuWax	EuRex	EuWax
Dt. Bank	Call	2	39	24:28	01:55	03:21	8.8%	4.0%	4.9%	3.3%	71.8%	12.8%
Daimler Chrysler	Call	1	13	20:31	02:51	03:30	21.9%	10.9%	12.9%	8.0%	84.6%	23.1%
		2	102	18:08	02:50	03:28	11.7%	8.3%	6.5%	6.3%	74.5%	8.8%
	Put	2	17	20:14	02:48	04:15	9.5%	5.0%	5.6%	4.4%	64.7%	5.9%
Deutsche Telekom	Call	1	19	21:49	03:43	03:17	10.7%	5.8%	5.6%	4.9%	73.7%	10.5%
		2	87	19:56	02:19	03:56	10.9%	7.2%	5.6%	4.9%	73.6%	26.4%
	Put	2	22	24:23	03:07	04:21	11.2%	10.1%	6.8%	5.1%	68.2%	63.6%
DAX	Call	3	840	15:20	01:49	02:20	7.1%	2.3%	3.7%	1.6%	70.8%	23.3%
Euro Stoxx 50	Call	3	51	21:21	01:47	03:28	7.5%	4.0%	3.2%	3.6%	84.3%	3.9%
Siemens	Call	2	61	20:03	01:46	03:22	12.1%	4.0%	7.1%	3.1%	75.4%	16.4%
	Put	2	10	08:25	01:32	03:02	5.6%	3.9%	4.0%	3.2%	70.0%	30.0%
All			1,261	19:31	02:24	03:29	10.6%	5.9%	6.0%	4.4%	73.8%	20.4%
All (Weighted)			1,261	16:57	02:00	02:46	8.3%	3.6%	4.4%	2.6%	72.2%	21.3%

Table 11: Brokerage Costs for EuRex and EuWax Options

The table shows EuWax DAX index option price (in Euro), number of EuRex contracts, trade value (in Euros), EuRex brokerage costs (in Euros), EuWax brokerage costs (in Euros), and the difference of EuWax and EuRex brokerage costs as a percentage of the trade value for three brokerages, Comdirect, Consors, and Fimatex. Contract size for EuWax and EuRex options is .01 Euros and 5 Euros per index point, respectively. Data on option characteristics are from EuWax, EuRex, and OnVista. Quote data are from EuWax and KKMDB. Brokerage cost data are from Comdirect, Consors, and Fimatex. Sample period is the year 2000.

			Brokerage Costs								
EuWax	# EuRex	Trade	Comdirect			Consors			Fimatex		
Price	Contracts	Value	EuRex	EuWax	Diff.	EuRex	EuWax	Diff.	EuRex	EuWax	Diff.
	1	525	19	1	3.4%	20	10	1.8%	13	9	0.7%
1.05	10	5,250	45	11	0.7%	39	18	0.4%	50	9	0.8%
	100	52,500	450	105	0.7%	275	69	0.4%	500	42	0.9%
	1	2,380	19	5	0.6%	24	11	0.6%	13	9	0.1%
4.76	10	23,800	45	48	0.0%	131	65	0.3%	50	19	0.1%
	100	238,000	450	476	0.0%	1,202	69	0.5%	500	47	0.2%
	1	3,830	19	8	0.3%	31	15	0.4%	13	9	0.1%
7.66	10	38,300	45	77	-0.1%	204	69	0.4%	50	31	0.1%
	100	383,000	450	766	-0.1%	1,927	69	0.5%	500	47	0.1%
	1	9,505	19	19	0.0%	60	29	0.3%	13	9	0.0%
19.01	10	95,050	45	190	-0.2%	488	69	0.4%	50.0	47	0.0%
	100	950,500	450	1,901	-0.2%	4,765	69	0.5%	500	47	0.0%

Table 12: Effect of EuWax Competition on EuRex Bid-Ask Spreads

The table shows the type (call or put), underlying asset (Deutsche Bank, Daimler Chrysler, Deutsche Telekom, DAX index, Dow Jones Euro Stoxx 50 index, and Siemens), number of daily observations, average time difference, average volume ratio, average ratio of ask prices, average bid-ask spreads (ratio of (ask minus bid) to ask), and t-statistics for the difference of the average bid-ask spreads for a sample of matched quote pairs of EuRex options with competition from EuWax options and EuRex options without competition from EuWax options during the year 2000. EuRex-EuRex quote pairs are generated by starting with a set of EuRex option quotes that have matching quotes from competing EuWax options. The EuRex quotes are matched to EuRex quotes for options without EuWax competition such that the matching EuRex option has the same type and underlying asset and comparable trading volume (as measured by paid premiums) during each observation month. Averages are calculated by first computing daily averages of observed quotes for each EuRex-EuRex option pair. The daily observations are then averaged by underlying asset and type. Simple and daily-observation-weighted averages of all measures are computed. Data on option characteristics are from EuWax, EuRex, and OnVista. Quote data are from EuWax and KKMDB.

Underlying Asset	Type	Daily Obs.	Time Diff.	No EuWax Comp. / EuWax Comp.		Bid-Ask Spread		
				Volume	Ask	EuWax Comp.	No EuWax Comp.	t-Stat.
Deutsche Bank	Call	1,540	1:16	.98	1.3	9.6%	13.9%	10.3
	Put	528	1:06	.99	4.0	14.6%	14.8%	.4
Daimler Chrysler	Call	1,608	1:19	1.00	2.3	18.3%	16.9%	(2.7)
	Put	1,051	1:24	.98	1.0	9.8%	11.4%	4.3
Deutsche Telekom	Call	2,641	1:18	.99	2.5	14.9%	14.7%	(.5)
	Put	1,420	1:13	.99	1.6	8.3%	10.2%	7.3
DAX	Call	6,452	1:27	.99	2.4	6.9%	9.5%	15.4
Euro Stoxx 50	Call	1,957	1:17	.98	1.8	7.8%	7.9%	0.4
Siemens	Call	1,549	1:33	.98	1.2	9.3%	12.5%	7.4
	Put	337	1:33	.99	1.1	7.6%	14.2%	7.0
All		19,083	1:21	.99	1.9	10.7%	12.6%	
All (Weighted)		19,083	1:22	.99	2.0	10.0%	11.7%	

Table 13: Effect of EuRex Competition on EuWax Bid-Ask Spreads

The table shows the type (call or put), underlying asset (Deutsche Bank, Daimler Chrysler, Deutsche Telekom, DAX index, Dow Jones Euro Stoxx 50 index, and Siemens), number of daily observations, average time difference, average volume ratio, average ratio of ask prices, average bid-ask spreads (ratio of (ask minus bid) to ask), and t-statistics for the difference of the average bid-ask spreads for a sample of matched quote pairs of EuWax options with competition from EuRex options and EuWax options without competition from EuRex options during the year 2000. EuWax-EuWax quote pairs are generated by starting with a set of EuWax option quotes that have matching quotes from competing EuRex options. The EuWax quotes are matched to EuWax quotes for options without EuRex competition such that the matching EuWax option has the same type and underlying asset, and comparable trading volume (as measured by paid premiums) during each observation month. Averages are calculated by first computing daily averages of observed quotes for each EuWax-EuWax option pair. The daily observations are then averaged by underlying asset and type. Simple and daily-observation-weighted averages of all measures are computed. Data on option characteristics are from EuWax, EuRex, and OnVista. Quote data are from EuWax and KKMDB.

Underlying Asset	Type	Daily Obs.	Time Diff.	No EuRex Comp. / EuRex Comp.		Bid-Ask Spread		
				Volume	Ask	EuRex Comp.	No EuRex Comp.	t-Stat.
Deutsche Bank	Call	6,763	2:26	.99	2.9	2.8%	1.9%	(15.6)
	Put	303	2:30	.96	9.3	5.7%	6.1%	.5
Daimler Chrysler	Call	4,751	2:28	.99	2.4	8.1%	7.7%	(1.8)
	Put	943	2:29	.99	2.1	2.5%	2.2%	(3.7)
Deutsche Telekom	Call	6,085	2:29	1.00	2.7	7.0%	6.4%	(2.9)
	Put	1,209	2:27	.99	.7	2.6%	7.5%	16.4
DAX	Call	25,322	2:25	1.00	4.9	1.3%	2.2%	20.9
Euro Stoxx 50	Call	3,381	2:25	1.00	3.0	3.4%	7.2%	15.8
Siemens	Call	4,752	2:28	1.00	2.4	2.8%	3.6%	6.5
All		53,509	2:28	.99	3.4	4.0%	5.0%	
All (Weighted)		53,509	2:26	1.00	3.7	3.1%	3.7%	